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Inorganic Chemicals: Prospects for Ontario's Industrial Minerals

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Executive Summary

THE PRIMARY AIM OF THE STUDY WAS TO IDENTIFY POTENTIAL commercial opportunities for industrial minerals—non-metallic, non-fuel minerals—in Ontario that result from growing or new North American markets for derived inorganic chemicals. Such opportunities could include the supply of provincial minerals to the North American chemicals market as well as the production of chemicals in Ontario from these raw materials.

The terms of reference for the study excluded fertilizer chemicals as well as products, such as surface-modified fillers, that do not undergo full chemical processing or transformation.

Approach of Study

The first stage of the study was an initial scan of inorganic chemicals to identify those with potential for market growth, technology change or possible market entry by an Ontario producer. More than four hundred chemicals were reviewed and some two hundred were given a preliminary rating as to their interest for further analysis. A rating system was devised to measure the assessment of the chemicals. The criteria for selection were as follows:

- viable regional market exists or could be developed;
- some growth or entry potential identified;
- possible base of provincial industrial minerals as raw materials.

This screening process led to the selection of 30 chemicals for further evaluation, based on their rankings in the initial survey or for their possible interest from an Ontario viewpoint in their entry potential. The short-listed chemicals were as follows:

Alumina trihydrate
Barium chemicals
Calcium carbide
Calcium carbonate
Calcium cyanide
Cesium and compounds
Europium oxide and derivatives
Fluorine/Hydrofluoric acid
Gadolinium and compounds
Gallium and compounds
Germanium and compounds
Magnesium carbonate
Magnesium chloride
Neodymium and compounds
Potassium carbonate
Potassium hydroxide
Rubidium and compounds
Samarium oxide and derivatives
Silica gels/sols
Silicon
Sodium aluminate
Sodium bicarbonate
Sodium chlorate
Sodium chlorite
Sodium cyanide

Sodium hydroxide
Sodium metabisulphite
Sodium nitrite
Titanium dioxide
Yttrium oxide and derivatives

In addition to the analysis of individual chemicals, research was extended to survey the outlook for consumption in five industrial sectors which used many of the chemicals under consideration. These sectors—pulp and paper, mining, ceramics, catalysts and electronics—were examined for possible "value-added" opportunities as many commodity chemicals could be considered for attractive specialty markets.

Chemicals Manufacturing in Ontario

Ontario dominates the chemicals manufacturing industry in Canada, accounting for over half of the nation's eighteen billion dollars in annual chemical shipments, and has an industrial inorganic chemicals sector which itself achieves annual shipments of over one billion dollars.

Table 1*
Ontario Industrial Chemicals‡ Industry: Annual Shipments

	1982	1984	1986
	($Cdn. million)		
Organic chemicals	2,410	2,756	2,473
Inorganic chemicals	1,210	1,229	1,131
Plastic resins	799	1,060	1,157
Agricultural chemicals	265 est.	300 est.	340 est.
Total	**4,684**	**5,345**	**5,101**

Sources: Statistics Canada; Law, Sigurdson & Associates.
‡ Excludes specialty chemical products such as paints, pharmaceuticals, soaps, cleaners, adhesives, etc.

The province offers many advantages as a location for new manufacturing enterprises. There exists a well-established mineral extraction and refining industry to provide needed metallic and non-metallic raw materials. It has a skilled labor pool of growing quality, reasonable energy costs, ready access to major domestic and U.S. markets, a strong industrial service infrastructure, and a vigorous research and development community focused on new manufacturing opportunities.

* Sources of all tables are Law, Sigurdson & Associates and/or SRI International, unless otherwise noted.

Potential Opportunities

Research and analysis focused on the markets for chemicals and aimed at providing information with which chemical firms or mineral producers could evaluate the business areas and determine whether they have any solid interest. Potential opportunities have been selected on the basis of growth in demand, coupled with a regional market base worthy of serious consideration, or of competitive positions that could be held or taken by an Ontario producer. Five such chemicals have been identified from the short-list of studied chemical products. They are as follows:

- Barium chemicals
- Calcium carbonate (precipitated)
- Colloidal silica
- Hydrofluoric acid
- Sodium cyanide

No engineering, costing or evaluation of raw material suitability has been done for these products. The focus has instead been on market and technology—in terms of growth and change—and the potential fit with Ontario, its regional base and raw materials.

The selection of these chemicals is qualified by their derivation, directly or indirectly, from industrial non-metallic minerals, as directed by the terms of the study.

Barium Chemicals

Barium chemicals could provide an opportunity, most probably for a small technical firm, based on a regional market and local raw materials. Over the past few years the major chemical companies have dropped out of this business, leaving only one basic barium chemical producer in North America, located in the state of Georgia.

Key to any development of barium chemicals would be the capacity to erect a plant that meets pollution control and occupational health standards with acceptable operating and capital costs. Plant operators would also have to know the chemistry and technology needed to operate the multi-stage process effectively. Licensing of technology may have to be considered.

Table 2
Canada and Northeastern U.S. Market for Barium Chemicals

	Canada	Northeastern U.S.	Total
		(kt)	
Barium carbonate	4.0	10.0	14.0
Barium chloride	1.5	4.0	5.5
Barium hydroxide	0.3	2.7	3.0
Barium sulphate	0.9	1.0	1.9
Miscellaneous	-	0.2	0.2
Total	**6.7**	**17.9**	**24.6**

We estimate the regional market to total 24.6 kt in volume and $(Cdn.)16 million in value for all chemical derivatives, excluding co-products, of barite. Canadian demand is only 6.7 kt. Since the domestic demand is insufficient to cover the production of a single plant, perhaps 20-30 kt, exports outside this base would have to be considered to sell the output.

Apart from base barium carbonate and barium chloride production, there are additional opportunities for carrying out further reactions, albeit at low volumes, to achieve value-added products that can serve the regional markets. Examples of downstream barium sulphide derivatives include barium hydroxide, high-purity barium chloride, barium titanates, barium ferrites and barium stearates.

Table 3
Barium Chemicals: Production Considerations

Raw materials	barite, coke, carbon dioxide
Typical plant capacity	20-30 kt/year
Typical capital cost	$20 - 40 million

Calcium Carbonate

Calcium carbonate offers potential for the Ontario lime producers to gear production to serve a growing demand in the province for precipitated calcium carbonate (PCC) in papermaking. There will also be growing potential for firms with the technology to make the product to establish plants—either on-site at paper mills or to serve regional mills.

The most significant market for calcium carbonate is for its use as a filler and coating ingredient in paper production. The entire paper industry is experiencing rapid growth coupled with a rate of technological change almost unprecedented in its history. The combination of these two factors has led to a complicated interaction of competing materials and some product scarcities. Major issues affecting paper chemical demand include: alkaline papermaking; 100 per cent water recycling; need for higher quality paper coatings; and changes in beater recipes.

Technology of production and knowledge of papermaking applications of precipitated calcium carbonate are probable key elements for this opportunity, as the mills making fine paper, in particular, change their technology to use carbonate filler instead of imported clays. A trend to alkaline paper-making (away from acid production) is driving the demand for calcium carbonate filler, replacing clay fillers used for acid paper production. Alkaline paper production not only allows calcium carbonate to be used, but also allows for greater filler levels. On fine papers such as the copy paper (i.e. xerographic) grades, savings of 25 to 33 percent are possible by switching to alkaline papermaking, increasing the percentage of filler in the paper and reducing the kraft pulp content.

Two grades of calcium carbonate will find increased use in alkaline fine papers—ground and precipitated. The precipitated type is used more for filler than as coating, since it has functional advantages in the former application. The more even particle size is giving PCC material preference over fine-ground carbonate. Both grades will grow in demand, but the precipitated grade is expected to grow faster.

The total North American market for PCC in 1988 was estimated to be 270 kt. Depending on end-use, prices varied from $(U.S.)200-$350/tonne. Total market value was in excess of $(U.S.)75 million.

Table 4
North American Outlook for Precipitated Calcium Carbonate

	1988	1993 (kt)	Annual Growth
Paper Filler and Coatings	180	400	12%
Paint and Plastics	26	30	2%
Other	64	70	2%
Total	**270**	**500**	**9%**

Pulp and paper applications are generally the only area of better-than-GNP growth for calcium carbonate.

Ontario, Quebec, New York, Ohio, Maine, Vermont and Pennsylvania comprise some 50 per cent of the continent's production capacity for fine papers. About 20-25 per cent of paper is now produced by the alkaline papermaking process and by 1995 it appears that upwards of 50 per cent of this sector will be producing alkaline paper. That could boost the consumption of calcium carbonate to an estimated 295 kt in the region. Demand for precipitated calcium carbonate is expected to increase faster than for ground material with the installation of on-site PCC plants at the larger mills.

Table 5
Estimated Regional Growth of Precipitated Calcium Carbonate

	1988	1995 (kt)
Northeast U.S.	105	240
Ontario/Quebec	2	55
Total	**107**	**295**

The production of precipitated calcium carbonate is generally carried out in on-site plants that can pump a slurry of product into the head-box of the paper machine. Only three or four firms have this technology and Pfizer Inc. dominates the field. Plants cost between $5 and $10 million and have a production capacity between 25 and 35 kt a year, sufficient to

supply one large papermill or several medium-sized ones in the same region.

Table 6
Precipitated Calcium Carbonate: Production Considerations

Raw materials	lime, carbon dioxide
Typical plant capacity	25-40 kt/year
Typical capital cost	~ $5-10 million

Colloidal Silica

The potential for an Ontario producer of colloidal silica is at least five years into the future, and by that time access to the papermaking market will have been clarified. An immediate potential for industrial minerals would be the supply of suitable sand to sodium silicate plants in Ontario and Quebec, which currently rely on U.S. raw material. Sodium silicate is the raw material for making colloidal silica.

Colloidal silica is a high-value, technically complex product of increasing importance in making fine paper. As the industry moves to alkaline papermaking and the technology of using higher filler levels develops, the demand for colloidal silica acting as part of a retention aid system is expected to rise. With a large portion of fine papers—particularly offset and copy papers—being produced in the Ontario regional market, a long-term opportunity could exist.

Table 7
U.S. Consumption of Colloidal Silica (100% SiO_2 basis)

	1988	1995	Annual Growth
	(kt)		
Investment casting	4.6	6.1	4%
Pulp and paper	3.2	6.9	12%
Wafer polishing	2.3	3.4	6%
Refractory binders	1.4	1.5	1%
Miscellaneous *	1.3	1.4	1%
Total	**12.8**	**19.3**	**6%**

* Includes catalysts, antiblocking agents, etc.

The pulp and paper market is really two sectors. In antislip coatings, growth will probably match that of linerboard production at 2-2.5 per cent annually. Silica-containing fiber retention systems are still in the introductory phases, and the speed with which they will be accepted is uncertain. Demand for these filtration/retention aids is expected to track alkaline papermaking. Neutral or alkaline sizing agents are becoming increasingly popular in some sectors of the papermaking industry, but penetration of these market sectors is not yet complete. Growth in silica demand may be quite rapid if mills accept these systems, but the growth will be from the very low currently-installed base.

Annual consumption of colloidal silica in Canada is 1,000-1,500 tonnes. Usage varies with the level of manufacturing activity in the paperboard and steelmaking industries, which together account for 80 per cent of consumption. Consumption in end-use markets is estimated to be: (a) paperboard, 55 per cent; (b) steel and foundry, 25 per cent; (c) other, 20 per cent.

The established market for colloidal silica has been the use in boxboard production pioneered by Du Pont several years ago.

Growth in paper application lies in the wet-end of paper machines as part of alkaline paper-filler systems, where the material helps impart filler retention and strength to the paper.

Table 8
Growth in Paper Applications for Colloidal Silica in North America

	1988	1995
	(kt)	
Boxboard	2.4	2.4
Fine paper	0.8	4.5
Total	**3.2**	**6.9**

The growth in colloidal silica in the regional market around Ontario will be tied to the use of the product in making paper. Application levels run at 1-4 kg per tonne of pulp. We estimate that the regional market will show a major swing to alkaline papermaking by 1995.

Hydrofluoric Acid and Fluorspar

The opportunity associated with hydrofluoric acid is basically for the supply of high-quality fluorspar to the local producer of this chemical. The demand for fluorine should rise as new generations of fluorocarbons are developed to replace the ozone-depleting types that are being banned, and the demand for hydrofluoric acid could rise as well.

The major opportunity would be for flotation processing of ore from an Ontario fluorspar deposit to serve the annual demand of approximately 150,000 tonnes in the province, which is currently met by imports.

Table 9
North American Consumption of Hydrofluoric Acid

Market	1974	1981 (kt)	1987	1995	Annual Growth '87-95 %
Fluorocarbons					
Aerosols	62	4	5	7	4
Refrigeration and air conditioning	35	86	95	140	5
Blowing Agent	10	35	40	60	6
Others	13	35	45	55	3
Aluminum manufacture					
Merchant	35	20	10	13	3
Captive	60	80	95	125	3
Gasoline alkylation	10	15	20	25	3
Stainless steel pickling	5	7.5	12	14	2
Uranium salt production	10	12.5	8	5	-6
Specialty metal manufacturing	5	8	12	18	5
Organic precursor	5	7	8	10	3
Other	50	40	30	23	-3
Total	**300**	**350**	**380**	**495**	**3.5%**

Hydrofluoric acid and fluorine chemicals are derived from fluorspar ore, a naturally-occurring calcium fluoride. While fluorspar's primary use is as a precursor for hydrofluoric acid and specialty organic and inorganic fluorides, it also finds significant use in the steel and aluminum industry, where it is used as a slag-fluxing material and for the production of synthetic cryolite. These applications are roughly 40 per cent as large as fluorspar use in hydrofluoric acid and specialty chemical production.

The most significant market for hydrofluoric acid is the chlorofluorocarbon (CFC) industry, where anhydrous hydrogen fluoride is the precursor for the production of such fluorinated aliphatic hydrocarbons as fluorocarbon 12, 22, 11, 113 and 116, materials commonly associated with the refrigeration and air-conditioning industries. The developing social and government awareness of the threat that these materials represent to the earth's ozone layer (and that layer's capability in ultraviolet filtering) has led to a reduction in consumption of these materials, and a worldwide dedication to the development of chemical alternatives for these materials by the year 2000. These alternatives are likely to contain higher levels of fluorine, as chlorine atoms on the molecules are replaced by fluorine, as well as hydrogen. The recent dip in demand for hydrofluoric acid in CFC production is therefore predicted to reverse. Some producers forecast that acid demand for CFCs could nearly double by 2000.

The regional market for fluorspar lies in the hydrofluoric acid area as well as in steelmaking and other applications. The acid-grade material which generally comes into Ontario from Mexico dominates the regional market, however, and this would seem to provide an opportunity for an industrial mineral producer.

Table 10
Value of Fluorspar Imports into Canada

	1986	1987 ($ millions)	1988
U.S.A.	2.4	2.2	2.6
Morocco	4.5	3.2	4.9
Mexico	11.3	7.6	15.3
China	0.5	1.7	1.9
Others	4.0	3.1	1.8
Total	**22.7**	**17.8**	**26.5**

Source: Statistics Canada

Annual fluorspar imports into Canada have been ranging from 135 to 194 kt. The low point in 1987 was due in part to a closure of Allied Chemical in Amherstburg for a few months, which necessitated the importing of acid into Canada as well as the cutback in rock imports.

The above figures include both high-grade fluorspar—CaF_2 content of 97 percent and above—and lesser grades below 97 per cent CaF_2. About 70 per cent of the material being imported into Canada from Mexico and other sources is the higher-quality material required for hydrofluoric acid production and some other applications.

Table 11
Volume of Fluorspar Imports into Canada

	1986	1987 (kt)	1988
U.S.A.	10.6	8.9	12.3
Morocco	27.6	22.5	34.0
Mexico	87.6	66.6	120.6
China	4.8	14.4	14.0
Others	33.5	22.2	13.2
Total	164.1	134.6	194.1

Source: Statistics Canada

Ontario obtains the bulk of its rock fluorspar from Mexico and most of this material is thought to account for the acid demand in the province.

Table 12
Value of Fluorspar Imports into Canada

	1988 ($/tonne)
U.S.A.	211
Morocco	143
Mexico	126
China	136
Average (weighted)	**136**

Product value varies somewhat, with the U.S. material obtaining a premium and Mexican material at the low end of the value-scale.

Sodium Cyanide

The potential for the manufacture of sodium cyanide lies in the strength of gold production in Ontario, Quebec and the U.S. regions in proximity to Ontario. The import demand in eastern Canada for cyanide has shot up over the past year and, should that level of consumption continue, there could be a prospect for sodium cyanide production in the province. There is no Canadian production of sodium cyanide and the nearest plant is in the southern U.S. Cyanamid Canada does compete in the sodium cyanide market with calcium cyanide, which is produced at Niagara Falls, Ontario.

Although we believe sodium cyanide represents an immediate potential opportunity, it should be kept in mind that the gold mining market is cyclical, and care should be exercised to ascertain the optimal timing for an investment.

Ontario has a good supply of raw materials and there exists a substantial and growing regional demand. The institution of a regional plant, perhaps delivering liquid material to Ontario and Quebec mines, might be feasible. The FMC Corp. plant in Wyoming could be leading the way towards the development of regional liquid plants, and its success will be watched carefully.

Table 13
North American Market Outlook for Sodium Cyanide

	1987	1988 (kt)	1995	Annual Growth
U.S.	45	52	100	10%
Canada	12	18	36	10%
Total	**57**	**70**	**136**	**10%**

Sodium cyanide (NaCN) is used primarily as a chemical reagent in the extraction of gold and silver. It is used in heap leaching of gold ores, as well as in further processing. The size of the U.S. market for sodium cyanide in 1987 was about 52 kt. At an average price of $(Cdn.)2,000/tonne, total market value was around $(Cdn.)105 million. With the addition of the Canadian market, which runs to $(Cdn.)27 million per year, the total North American demand for sodium cyanide comes to $(Cdn.)132 million. The North American calcium cyanide market could also account for an additional $15-20 million of sales per year.

The U.S. market for sodium cyanide is expected to grow at an average annual rate of about 10 per cent. Some growth estimates are as high as 15 per cent and have been advanced on the anticipation of rapid increases in gold mining activity. Technological change in gold and silver extraction methods is not expected to affect this market within the next 10 years.

There is no production of sodium cyanide in Canada, so Canadian users, unless they can use and have access to the calcium cyanide material sold by Cyanamid, must rely on imported material. In 1988, one-third of the sodium cyanide was brought in to Canada from Tennessee. Other major exporters to Canada included West Germany and the United Kingdom.

Table 14
North American Supply/Demand: Sodium Cyanide

	U.S.	Canada (kt)	North America Total
Capacity	100	-	100
Production	80	-	80
Offshore imports	13	12	25
(U.S. to Canada)	-	(6)	(6)
Net total supply	93	18	105 Net
Domestic demand	52	18	70
North American exports	41	-	35 Net

Predicting the growth in demand for sodium cyanide for gold production is difficult, since the volume used can vary significantly with the price of the precious metal in world markets. We have assumed a 10 per cent growth rate to 1995. Several new production facilities have been announced, and that capacity may be built depending on the shifts in the North American and international markets. Any facility located in Ontario would need to carve out a regional position, based on service and transportation advantages, over the continental and international suppliers.

Table 15
Forecast North American Supply/Demand: Sodium Cyanide

	1988	Case 1 1995 (kt)	Case 2 1995
Capacity			
Du Pont	100	170	170
FMC	-	22	22
Degussa	-	30	30
Possible Ontario facility	-	-	30
Total announced capacity	100	222	252
Production	80	175	202
Imports	25	-	-
Total supply	105	175	202
Domestic demand - U.S.	52	100	100
- Canada	18	36	36
Total domestic demand	70	136	136
Total exports	35	39	66

The above projection could be conservative. Some industry sources have predicted 15 per cent growth. The tendency in the mining industry is that when gold runs over $(U.S.) 400 an ounce, gold mining increases solidly, and then it slowly tails off as it drops below $(U.S.)350 per ounce. Demand for cyanide should therefore be quite sensitive to the price of gold. As a result, many industry watchers are expecting gold production to rise in the order of 10-15 per cent and cyanide consumption along with it over the next five or more years.

There are new mines coming into production as the price of gold has increased over the past several years. Current production costs leave enough margin to keep plants operating and allow some new ones to come on-stream.

Although demand for sodium cyanide is assumed to be growing at relatively high rates, the capacity build-up in North America will be even faster, and capacity should still exceed demand by 1995. This is based on announced capacity from the major producers.

For North America as a whole, domestic production will have to be exported to fill out plant capacities. A scenario that involves an Ontario operation would force southern U.S. producers to export their output offshore. Additionally, an Ontario-based plant would have to replace much of the offshore imports heading into Canada at the present time.

Table 16
Regional Market Coverage for Ontario Plant (Sodium Cyanide Only)

	1988	1995 (kt)	1995 Sales Share Needed
Ontario	6	12	80%
Quebec	4	9	80%
British Columbia	4	8	60%
Northwest Territories and Yukon	2	4	50%
All other areas	2	3	60%
Total	**18**	**36**	**75% ***

* 75% share is 27 kt.

The opportunity in Ontario is based on being a strong regional supplier. There would seem to be enough market coverage to fill out the major portion of a 30 kt plant. An Ontario producer would have to capture nearly 80 per cent of the eastern Canadian market, as well as a major portion of western Canadian market, moving material by rail to as far away as British Columbia and the Territories. If Du Pont can place material from Tennessee in the western Canadian market, then an Ontario-based plant should be able to be competitive on transportation.

An Ontario facility could be sized to supply a 27 kt market, with a strong emphasis on sales in Ontario and Quebec. In the eastern Canadian market, an Ontario producer should have an advantage over European imports. Not only would there be a transportation advantage, but the producer could sell directly, eliminating distributor mark-ups.

Table 17
Production Considerations: Sodium Cyanide

Raw materials	Ammonia, caustic soda
Typical plant capacity	20-50 kt/year
Typical capital cost	$50 million

Ontario has a good supply of both ammonia and sodium hydroxide to support any sodium cyanide facility. Although the volume of mineral sodium chloride would not affect significantly the high-volume salt business, a sodium cyanide facility based in Ontario is attractive to the mining industry. Not only would there be a local supplier of the chemical, but a mining company could consider entry into the market, serving its own requirements as well as selling merchant volume.

Impact on Industrial Minerals of Ontario

The impact of the chemical opportunities on Ontario's industrial minerals sector will be highly varied. Demand from any of these chemical opportunities, if they are successfully implemented, may not result in the opening of many or any mines. However, the opportunities can provide additional market volume or value-added products for the existing mineral sector in the province.

Table 18
Maximum Potential Requirement for Minerals

Chemical	Raw Material	Mineral Requirement Annual Volume (tonnes)
Hydrofluoric acid	Fluorspar	150,000
Calcium carbonate, (precipitated)	Limestone	200,000
Barium chemicals	Barite	25,000
Cyanide	Caustic soda/salt	15,000
Colloidal silica	Silica	5,000

The chemicals analyzed in detail as opportunities from an industrial mineral view-point have as raw materials fluorspar, limestone and its derivative lime, barite, salt and its derivative sodium hydroxide, and silica.

Opportunities already exist to supply industrial minerals such as fluorspar, limestone and silica to the chemical producers in the province, providing deposits of suitable quality can be found or processing technology employed to upgrade Ontario resources to acceptable specifications. These raw materials are presently being imported into the province to make inorganic chemicals. Indications were found that local supply could be considered if the proper quality of raw materials could be made available. These minerals could therefore offer an immediate opportunity for the industrial minerals producer.

The dollar volumes of the chemicals identified vary widely. The level of investment and technical skills are also disparate. The regional volume of the chemicals has been judged approximately sufficient to provide the initial base for a plant investment for each of the products identified. Lack of engineering cost data on most of the plants leaves open the question of whether the capital cost of a plant can be supported by the current selling prices of the products and the volume of business in the regional market or beyond.

Table 19
Estimated Regional Market Volume

	Regional demand ($ million/year)
Cyanide	35
Fluorspar	25+
Calcium carbonate, precipitated	20+
Barium chemicals	16
Colloidal silica	5

In examining the chemicals/minerals and identifying the growth outlook, timing is a major consideration. Some of the products have immediate potential - such as the barium chemicals, cyanide and fluorspar. It is estimated that the potential for entry in precipitated calcium carbonate manufacture lies in the medium term of two to five years. The sales of silica to the sodium silicate business in Ontario and Quebec could commence immediately, even though it is estimated that the colloidal silica potential will not be realized for another five or more years.

1. Introduction

This study was commissioned by the Mineral Development and Lands Branch of the Ontario Ministry of Northern Development and Mines. Funding was provided by the Economic Development Program of the Canada-Ontario Mineral Development Agreement (COMDA). COMDA is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the Governments of Ontario and Canada in 1984.

Terms of Reference

The principal aim of the study was to identify potential commercial opportunities for industrial minerals in Ontario that result from growing or new North American markets for derived inorganic chemicals. Such opportunities could include supplying provincial industrial minerals to the North American chemicals market as well as producing chemicals in Ontario from these raw materials.

For the purposes of the study, an industrial mineral is defined as any rock, mineral or derivative thereof, excluding mineral fuels, that is exploited for non-metallic values by conversion to inorganic chemicals. The field of inorganic chemicals to be reviewed was reduced by specifically excluding those chemicals or portions thereof used in fertilizers. Products which are solely the result of treatment by surface modification and are not subjected to full chemical processing or transformation, such as coated mineral fillers and extenders, were also excluded from the study.

Methodology of Study

The initial step in the study was a general examination of mineral-based inorganic chemicals to identify areas that were considered worthy of closer investigation. The field of chemicals under study was progressively narrowed in defined stages. The steps in developing the study were as follows:

1. Initial scan for commercial inorganic chemicals - 400 chemicals.
2. Rating of approximately 200 chemicals for growth, technology change, and Ontario's position.
3. Selection of 30 chemicals for detailed study.
4. Evaluation and selection of potential opportunities included examination of major industrial consumer segments.
5. Detailed examination of the market factors involved in five chemicals selected as potential opportunities.

In the context of this study "potential opportunities" focused on chemical, rather than physical, processing of industrial minerals. The upstream integration of chemical consumers to mineral producers was a secondary consideration.

The initial scan of some 400 chemicals and the closer survey of some 200 chemicals resulted in a reduction of this number to 30 that were identified as meriting detailed examination. This evaluation process leading to the selection of the 30

chemicals was conducted by Law, Sigurdson & Associates.

When the study progressed to the research of a selected short-list of chemicals, SRI International's database on chemicals and chemical processes was used to provide the wider perspective in the study, and the regional detail was supplied by Law, Sigurdson & Associates.

In addition to the chemical-by-chemical analysis, an examination was made of some major industrial sectors that consume inorganic chemicals on a volume basis. The purpose of this analysis of specific industrial areas was twofold:

(a) to identify any multi-chemical or service oriented inorganic business potential

(b) to provide background information on some of the individual chemicals, since most of them have major consumption in one of the five selected business areas, namely pulp and paper, mining, electronics, ceramics and catalysts.

In the chemicals industry generally there is a trend to specialization and "value-added packages" of product, equipment and technical support. Research and analysis of industry sectors were directed to identify such tendencies and look for potential in a regional context. The search was for groups of chemicals sold on a service basis to a particular industry. Suppliers of such "value-added packages" often are not basic in all chemicals they sell, but have invested in the application technology to the extent that they blend or formulate products for specific industries.

For several of these "packages" the differentia are not so much the composition of the chemical, but rather the purification processes needed to refine the initially-extracted chemical to the purity demanded by the use. Many commodity chemicals with mature applications could therefore be considered for more attractive specialty markets. Additionally, this sectorial analysis provided a landscape of the market in which many other chemicals are sold.

Selection Criteria

In examining the potential opportunities for inorganic chemicals in an Ontario context, emphasis was placed on any possibilities for entry, not simply aggregate market growth. Given careful consideration were factors such as regionalization of markets, technological change and cost factors.

Generally, inorganic chemicals have not undergone the same technological or market expansion as have organic chemicals in the past two decades. Many of the commodity inorganic chemicals often are highly mature products, and both market growth and technological change may not be evident. Therefore concentration was placed on technology factors, not in the production of chemicals but rather in the markets that could be developed for them.

The criteria for selection are listed as follows:

- Viable regional market exists, or could be developed;
- Some growth or entry rationale or entry potential identified;
- A base or connection to industrial mineral raw materials that exist in Ontario.

In setting general selection criteria, emphasis was placed on the need for a local market to support any chemical manufacturing operation. Without customers close to the supplier, entry is often difficult. In addition, the specialization of the chemicals industry often means that sophisticated customers can provide a chemical manufacturer with technical problems to solve and in turn develop its product line and product sophistication. So, increasingly in the specialty portion of the chemicals markets, smart customers beget sophisticated suppliers, and vice-versa.

Based on the existence of a regional market, the second criterion was the ability to develop an entry rationale for the chemical under consideration. Factors such as market growth, market regionalization, technology change, or product specialization were considered in trying to identify an entry rationale for the chemicals under analysis.

The last criterion was an examination of the raw material or market position that Ontario might have for the potential business opportunity. An examination was made of the strengths and potential "edges" that might exist for an Ontario producer of the chemical under consideration.

2. Ontario and the Chemicals Industry

Chemicals Manufacturing in Ontario

Ontario dominates the chemical industry landscape in Canada, accounting for well over half the nation's $18 billion of annual chemical shipments. The province lays claim to a solid 51 per cent share of the $10 billion output of the industrial chemicals sector. And even this is surpassed by a striking 64 per cent share of the annual $8 billion in national shipments by the specialty chemicals sector (pharmaceuticals, paints, detergents, etc.).

The province is the leading producer in every chemical industry subsector, save agricultural chemicals, in each case generating at least half, and often much more, of national output.

Table 2.1
Canadian Chemical Industry Shipments, 1986

	Canada	Ontario
	($ million)	
Industrial chemicals:		
Inorganic chemicals	2,183	1,131
Organic chemicals	4,350	2,473
Fertilizers	914	170 (est.)
Mixed fertilizers	258	42 (est.)
Other agricultural chemicals	318	128
Plastic resins	1,969	1,157
Subtotal	9,992	5,101
Specialty chemicals:		
Pharmaceuticals	2,489	1,376
Paint and varnish	1,243	817
Soaps and cleaners	1,507	1,299
Toiletries preparations	944	526
Adhesives	188	148
Other chemical products	1,907	1,141
Subtotal	8,278	5,307
Total	**18,270**	**10,408**

In the area of inorganic chemicals manufacturing, the focus of this report, Ontario again is dominant nationally. Its 52 per cent of national shipments are worth in excess of $1 billion annually. The province is host to 36 of the 104 major inorganic chemicals producers in Canada, with an employment roster of 2,240 out of a national figure of 5,000.

While the inorganic chemicals manufacturing group in Ontario is well-established and profitable, it has shown lackluster overall growth in the 1980s (Table 2.2). Business health tends to be largely a function of general economic conditions. Indeed, negligible growth in the past decade has characterized the industrial chemicals sector in Canada as a whole, save for

plastic resins. During the 1980s, obsolete petrochemical plants were replaced with world-scale units. As a result, Canadian chemical producers became more internationally competitive and more focused.

Plastic resins have been the only major growth area for the commodity chemicals in recent years in Ontario. Plant expansions and increased value of product have combined to increase the shipment values from that sector of the Ontario chemical industry.

Table 2.2
Structure of Ontario Industrial Chemicals Industry

	1982	1984	1986
	Shipments ($ million)		
Organic chemicals	2,410	2,756	2,473
Inorganic chemicals	1,210	1,229	1,131
Plastic resins	799	1,060	1,157
Agricultural chemicals	265e	300e	340e
Total	**4,684**	**5,345**	**5,101**

Sources: Statistics Canada; Law, Sigurdson and Associates
e = estimate

Production Advantages in Ontario

Ontario offers a number of advantages as a location for new manufacturing enterprises. This section examines six inherent structural factors that should particularly appeal to an inorganic chemicals producer wishing to serve regional markets. These factors are:

- Favorable power rates in comparison with most of North America;
- Nearby and improving access to major markets;
- A skilled labor pool of growing quality;
- A vigorous research and development community;
- A pre-existing chemicals service infrastructure;
- Raw materials base with added potential.

Electrical Power

In terms of both cost and availability, Ontario electrical power ranks quite competitively on a regional basis in northeastern North America. The province has a well-developed electrical generation capability and sufficiently abundant power to be able to export to the U.S.

Table 2.3
Typical Ontario Industrial Energy Costs

Electrical energy	4.5-6¢/kWh
Natural gas	11-16¢/cu meter
Heating oil	30.9¢/litre

Ontario electricity rates to larger power users, such as chemical plants, are very competitive in comparison with most U.S. states. In Canada, urban electric power costs are lower in Manitoba, British Columbia, Alberta and Quebec than in Ontario. Comparing power rates in North American chemical centers (Table 2.4), Ontario is 17 per cent cheaper than Texas and 34 per cent cheaper than Chicago. However, against low-cost power centers such as the Tennessee Valley and Bonneville power authorities, the rates in Ontario offer little major advantage.

Ontario Hydro, the provincially-controlled and sole electric power supplier, operates a user-pay policy and essentially has a single uniform rate for large industrial users. This means that there has been no cheap power offered for specific areas or for regional development. Over the past year the power utility has introduced a program of off-peak power use that reduces power costs substantially for night-time and weekend use. Thus energy-intensive industries, such as the abrasives industry in the Niagara Falls area, are able to achieve substantial economies.

Although Ontario has favorable rates when compared to many locations in North America, specific regions offer favorable rates on an on-going basis to preferential customers. Quebec and some areas of the state of New York have attracted major electrical power-intensive businesses.

Table 2.4
Comparative North American Electrical Power Costs for Industrial Users (100,000-400,000 kWh Class)*

	1988	1987
	('000 $Cdn.)	
Winnipeg	13.6	13.0
Vancouver	16.1	16.1
Calgary	16.6	16.6
Montreal	18.7	18.0
Ontario (urban)	19.5	18.5
Fredericton	20.5	20.5
Ontario (rural)	21.1	20.1
Dallas	25.5	25.9
Louisville	24.2	25.9
Detroit	34.3	37.2
Chicago	34.3	44.9
St. Louis	35.4	38.6
Boston	39.2	42.6
New York	45.4	53.5

* Monthly total bill, excluding local charges and taxes
Source: Ontario Hydro

In summary, Ontario, with its good mix of hydro, nuclear and thermally generated electricity, remains relatively competitive among other industrial provinces and highly competitive with most regions in the United States.

Access to major regional markets

A major advantage for manufacturers located in Ontario is rapid and convenient access to a number of major domestic and U.S. metropolitan and industrial markets. Within one day's trucking from Toronto, for example, there is a population of 105 million, and within a two-day trip there is a 165 million population. In short, over 50 per cent of the population of Canada and the U.S. lies within two days' trucking from Toronto. This highly favorable market geography is particularly advantageous to producers of many specialty inorganic chemicals. Within this region there are also major industrial sectors - i.e. automotive, pulp and paper, petrochemical and steel production.

Sample distances of Metropolitan Centres from Toronto by truck shipment are as follows:

One day:
New York, New York
Newark, New Jersey
Wilmington, Delaware
Boston, Massachussets
Detroit, Michigan
Pittsburgh, Pennsylvania
Philadelphia, Pennsylvania
Washington,D.C.
Cincinnati, Ohio
Cleveland, Ohio
Chicago, Illinois

Two days:
Atlanta, Georgia
Minneapolis, Minnesota
Charlotte, S. Carolina
St. Louis, Missouri
Nashville, Tennessee
Richmond, Virginia

The regional market can offer not only a transportation advantage but a service advantage for interested product suppliers as well.

Canada-U.S. Free Trade Agreement will facilitate cross-border trade and improve access to U.S. markets for Ontario manufacturers in general and chemical producers in particular. Generally, the two countries will dismantle existing tariffs on chemicals over a five-year period. Tariffs on processed or finished products will be phased out over 10 years. When implemented, the trade pact will effectively give many inorganic chemicals duty-free status within a couple of years.

The duty rates on chemicals between Canada and the U.S. have tended to be high on organic products and lower on inorganic. So, many basic acids and alkali products have for years moved duty-free across the border, while the more specialty chemicals have faced tariff levels upward of 10-15 per cent. The impact of the Free Trade Agreement will be most felt by the specialty chemicals—which means that market restructuring opportunities could come to Ontario in some of the specialty products being examined in this study.

Labor pool

Ontario has a strong labor infrastructure in terms of support for sophisticated industries required by the chemicals industry. The labor force is well educated and more than 30 per cent has some post-high school education.

Table 2.5
Ontario Workforce: Education Level

	Ontario	Canada
	(% population)	
0-8 grade	15.2	17.7
High school	49.7	49.0
Some post-secondary	10.0	9.3
Post-secondary diploma	12.6	12.7
University degree	12.5	11.3
Total	**100.0**	**100.0**

* Workforce over 15 years old
Source: Statistics Canada

The future quality of the Ontario labor pool at the management, supervisory and technical levels can be expected to improve still further. Ontario has a highly effective educational system, with nearly half of students in high school going on to university or post-secondary education (Table 2.6). The universities and technical institutes work closely with industry to ensure a flow of graduates with appropriate scientific and technical skills. Special provincial programs supplement these efforts.

Table 2.6
Percentage of Ontario Students Attending Post-Secondary Institutions

Universities	15%
Institutes and special colleges	7%
Community colleges	22%

Research activity in the chemical industry

Two-thirds of all the chemical industry's research and development spending in Canada takes place in Ontario. The province's share of R and D outlays is similarly high in metals and many other basic manufacturing industries.

Table 2.7
Ontario Share of R and D Activity in Canada

Chemicals	66.3%
Metals	66.0%
Electrical/electronics	72.6%
Machinery and transportation equipment	66.0%
Wood products	24.9%
Mining and oil wells	66.0%
Other manufacturing	65.6%
Total Ontario Share	**60.4%**

Source: Statistics Canada

Two years ago the Ontario government set up a $200 million program to foster basic and applied research in the universities to meet the needs of selected industries in the province. Seven "Centres of Excellence" were established to undertake research and product development in targeted areas. Industry and university representatives sit on the governing boards of the centres to provide focus and direction for their work. Development of joint R and D programs with industry is one of their key functions.

The centres are:

- Ontario Centre for Materials Research
- Telecommunications Research Institute of Ontario
- Ontario Laser and Lightwave Institute
- Waterloo Centre for Groundwater Research
- Information Technology and Research Centre
- Institute for Space and Terrestrial Science
- Manufacturing Research Corporation of Ontario

A number of potential new applications for inorganic chemicals fall within the orbit of these research fields, specifically in such areas as telecommunications, advanced materials, and lasers. Hence the centres could serve to support development ventures in specialty chemicals for selected "high-tech" markets.

Infrastructure

In Ontario, chemical producers—both organic and inorganic—have tended to locate near the major petrochemical plants in Sarnia and the Belleville-Cornwall corridor. The major exceptions are the inorganic chemical plants that produce acids from the smelter gases at Sudbury or service-specific plants in the pulp and paper industry.

The size and location of the chemicals industry in Ontario has led to the development of a reasonable service infrastructure in southwestern and eastern Ontario. These regions have attracted a variety of service companies offering specialized testing, distribution, maintenance and similar services to chemical producers.

Much of Ontario's inorganic chemicals production is oriented to serving the pulp and paper and mining industries in the province. These industries in turn could provide raw material support for further development of inorganic chemicals manufacturing in Ontario, since they are ready sources of many acids, alkalis and solvents.

Raw materials from Ontario minerals

A number of Ontario minerals and mineral refining by-products that could serve as raw materials in inorganic chemicals manufacture can be identified. These "new opportunity" minerals exist either as presently non-utilized major ores or as non-utilized minor components (mostly metallic) of major presently-exploited ores. The latter group of minerals are recovered either at the primary ore processing stage or as a by-product of the smelter refining operation. In some cases, the new identified opportunities are for minerals already widely used in chemicals production, as in the case of sodium chloride (salt).

Ontario's mineral producers shipped approximately 33 different mineral types in 1987 with a combined value of $4.2 billion (excluding fuels and structural materials). The metallic minerals segment, including copper, nickel and zinc, accounted for $4 billion of the total. The remaining $244 million was in shipments of non-metallic minerals such as silica, nepheline syenite, gypsum, limestone, talc and dolomite. By comparison, Saskatchewan's potash industry, Quebec's asbestos and titanium dioxide industry, and Alberta's sulphur production contribute significantly to those provinces, having larger non-metallic mineral sectors than Ontario.

Table 2.8
Non-metallic Minerals Exploited in Ontario

Barite	Quartz
Limestone	Salt
Dolomite	Serpentine
Gypsum	Sulphur (byproduct)
Magnetite	Talc
Nepheline Syenite	Yttria-bearing minerals

Primary minerals identified as chemical raw materials

Several of Ontario's primary industrial minerals could find new applications as raw materials for the manufacture of types of inorganic chemicals not presently being produced in the province. Some of these, like sodium chloride, are already being used in chemicals production in the province.

Table 2.9
Primary Minerals with Raw Material Potential for Inorganic Chemicals Production

Mineral	End Uses
Magnesite	Magnesium chloride
Barite	Barium chemicals
Sodium chloride	Sodium hydroxide, chlorine Sodium chlorate
Limestone	Precipitated calcium carbonate
Silica sand	Silanes/silicates

Mineral by-products as raw materials

The minor mineral components of presently-utilized parent ores could serve as raw materials for inorganic chemicals production. These minor components are usually metallic in nature and frequently have high-value, high-tech applications. Such metallic elements are recovered from ores in either the primary ore processing phase or in metal smelter refining. In the latter case, they may emerge in flue gases as dust and are usually produced in low concentrations, needing further refining.

Chemical elements with inorganic chemicals production potential are found in trace amounts in the sulphide ores of the Sudbury basin, in the Elliot Lake uranium ores or in the base metals of northern and northeastern Ontario. There are several major nickel, uranium and base metal processing and smelter operations in the province that could serve as a source for these elements. Many of these remain unrecovered, including several chemical elements of the important rare-earth group. Among metallic elements that are being recovered for commercial use are yttrium and several platinum-group elements, such as rhodium and iridium. Non-metallic elements being used include tellurium and selenium. Selenic acid and selenious acid (and their salts, selenate and selenite) are also being recovered commercially.

Table 2.10
Secondary Mineral By-products with Potential for Inorganic Chemicals Production

Dysprosium	Platinum
Indium	Rhodium
Iridium	Ruthenium
Neodymium	Selenium
Osmium	Tellurium
Palladium	

Summary of Ontario strengths

Ontario's strengths for inorganic chemicals development lie in the strongly supportive industrial and social infrastructure and its favorable geographical position in relation to markets.

The raw material resources of the province offer some base for new developments, although none of the major opportunities is likely to have been overlooked by the sophisticated and aware mineral producers now operating in the province. The Ontario minerals industry generally operates on a global rather than regional basis. Any involvement by the industry in development of inorganic chemicals manufacturing ventures geared to markets near the province would most likely come through partnership with chemical firms which have specialized technology, or simply as suppliers of the requisite mineral products as raw materials.

There may be some opportunity for provincial co-operation with chemical firms, mining companies or entrepreneurs to develop specialized inorganic chemicals manufacturing enterprises based on provincial minerals and their by-products. Such ventures may present an opportunity to establish a technology-based specialty chemicals position in North American markets.

Ontario is well served in terms of electrochemical production or refining of chemicals. Many inorganic chemicals use electrical energy in purification, and this could be a favourable edge in specific instances.

The major business strengths of Ontario for inorganic chemicals development are summarized as follows:

- nearby large regional markets with improving access;
- reasonable energy costs;
- trained labor force;
- good chemicals industry infrastructure;
- solid R and D and university infrastructure;
- potential raw materials base.

3. Initial Scan of Inorganic Chemicals

Introduction

The first step in the development of the study was a brief scan of inorganic chemicals to identify those with potential for growth and market change. This work was carried out by Law, Sigurdson & Associates.

More than four hundred chemicals were reviewed and some two hundred were given an initial rating as to their interest for further analysis. An arbitrary minimum level of commercial activity was required for a chemical to be considered and rated for potential.

Preliminary Rating of Chemicals

Product Rating System

A rating system was devised to provide a measure of the qualitative assessment that was made on the chemicals.

Each of the important commercially-produced inorganic chemicals that can be derived from industrial minerals was reviewed with respect to the current level of production in North America, competitive processes for its manufacture, the leading suppliers in North America and elsewhere and market prospects in the major end-use categories. On that basis, a maximum of 10 points could be assigned to products demonstrating double-digit annual growth rates over the next five years—a very rare occurrence indeed!—and additional points were given if some technological breakthrough promised expanded markets beyond the five-year horizon. Other possitive considerations were such factors as high electrical energy inputs—the assumption was that Ontario's power rates are lower than most other jurisdictions—and the possibility of import replacement.

There were negative factors as well. Detracting from the maximum rating were the following considerations:

1. present over-capacity delays the need for new suppliers (conversely, withdrawal of an existing producer is to the advantage of a potential new supplier);
2. production economics work against a new grassroots supplier;
3. raw material costs are insignificant in over-all economics;
4. product is ultimately derived not from industrial minerals but from metal mining or hydrocarbon processing;
5. transportation costs militate against production in Canada;
6. existing patent protection complicates production in Canada.

Ratings were established for each chemical or chemical group using the above-mentioned criteria and listed with values under the categories A to H. These were defined as follows:

Factors	Max.Rating
A=Market growth over next five years	±10
B=Longer-term growth potential based on new technology	±2
C=Supply/demand balance (oversupply is a negative)	±2
D=Economic factors (power costs, etc.) favoring Ontario	±2
E=Raw material advantage largely immaterial	±1
F=Raw material source either remote or associated with metal mining or hydrocarbon sources	±1
G=Shipping costs to market are significant	±1
H=Access to technology is restricted	±1

Rating of Chemicals

The rating of some chemicals was done as part of groups of chemicals. Groups were defined by their major constituent and/or position on the periodic table, not necessarily on their method of production. The chemicals initially considered as commercial products and their overall rating by Law, Sigurdson & Associates are shown in Table 3.1.

Table 3.1

Initial Rating of Inorganic Chemicals (alphabetical order)

Chemicals and compounds	Rating
Aluminum alkyls	4
Aluminum chlorhydrate	0
Aluminum chloride	2
Aluminum fluoride/sodium fluoroalum	1
Aluminum oxide (alumina)	2
Aluminum sulphate (alum)	-1
Aluminum trihydrate	4
Ammonium chloride	2
Ammonium tungstate	-1
Antimony oxides	1
Arsenic acid	0
Arsenic meta	1
Arsenic trioxide	-1
Barium carbonate	-1
Barium chloride	1
Barium oxide, hydroxide	2
Barium sulphate (incl. blanc fixe)	1
Barium sulphide	1
Beryllium oxide	3
Bismuth metal	-1
Bismuth nitrate and other salts	-1
Boric acid	0
Bromine	1
Cadmium and its compounds	0
Calcium bromide	3
Calcium carbide	5
Calcium carbonate	4
Calcium chloride	-1
Calcium cyanamide	0
Calcium cyanide	-2
Calcium hypochlorite	1
Calcium metal	3
Calcium nitrate	2
Calcium oxide, hydroxide	3
Calcium phosphates	1
Calcium silicates	1
Carbon disulphide	0
Cerium oxide and derivatives	3
Chlorine (elemental)	2
Chlorosulphonic acid	0
Chrome pigments (lead chromate, etc.)	0
Chromium oxides	1
Chromium sulphates	-2
Chromium-based catalysts	1
Cobalt and other ferrites	1
Cobalt carbonate	1
Cobalt hydroxide and sulphate	1
Cobalt nitrate	2
Cobalt oxides	4
Copper compounds, misc.	1
Copper sulphate	0
Europium oxide and derivatives	4
Ferromolybdenum	-1
Gadolinium oxide and derivatives	6
Gallium and compounds	6
Germanium and compounds	6
Gold and compounds	1
Hydrofluosilicic acid	0
Hydrogen chloride (hydrochloric acid)	0
Hydrogen fluoride (hydrofluoric acid)	1
Hydrogen sulphide	1
Indium and compounds	5
Iodine	0
Iridium and compounds	1
Iron chlorides	0
Iron oxides	1
Iron sulphates	3
Kaolin	4
Lanthanum oxide and derivatives	3
Lead compounds, misc.	-1
Lead oxides	-1
Lithium carbonate	2
Lithium chloride	2
Lithium hydroxide	0
Lithium metal	1
Lithium sulphate	1
Lithium, n-Butyl	1
Magnesium alkyls, Grignard reagents	4
Magnesium aluminate	0
Magnesium carbonate	2

Magnesium chloride	3
Magnesium hydroxide	0
Magnesium oxide (magnesia)	3
Magnesium silicates (incl. talc)	2
Magnesium sulphate	3
Manganese chloride	-1
Manganese dioxide	0
Manganese metal	0
Manganese sulphate	-1
Mercury and its compounds	-3
Molybdenum disulphide	0
Molybdenum powder	-1
Molybdenum trioxide	-1
Neodymium oxide and derivatives	4
Nickel chloride	4
Nickel oxides	4
Nickel sulphate	4
Niobium and compounds	3
Osmium and compounds	1
Palladium and compounds	1
Phosphoric acid	1
Phosphorus (elemental)	1
Phosphorus oxychloride	1
Phosphorus pentasulphide	2
Phosphorus pentoxide	2
Phosphorus trichloride	1
Platinum and compounds	1
Potassium carbonate	5
Potassium chlorate	2
Potassium hydroxide (caustic potash)	5
Potassium permanganate	-1
Potassium phosphates	1
Praseodymium and derivatives	2
Radium and compounds	-2
Rare earth oxides, mixed	0
Rhodium and compounds	3
Rubidium and compounds	5
Ruthenium and compounds	1
Samarium oxide and derivatives	5
Selenium and compounds	2
Silica gels/sols (colloidal silica)	4
Silicon dioxide	2
Silicon metal	4
Silver and compounds	0
Sodium aluminate	4
Sodium aluminum silicates	0
Sodium and ammonium metavandates	0
Sodium and ammonium molybdate	-3
Sodium bicarbonate	5
Sodium bisulphites	5
Sodium borohydride	3
Sodium carbonate (soda ash)	0
Sodium chlorate	6
Sodium chlorite	4
Sodium cyanide	5
Sodium dichromate	0
Sodium fluoride	1
Sodium hydrosulphide	2
Sodium hydrosulphite (sodium dithionite)	1
Sodium hydroxide (caustic soda)	5
Sodium hypochlorite	2
Sodium metal	3
Sodium nitrate	1
Sodium nitrite	4
Sodium perborate	2
Sodium peroxide	2
Sodium phosphates	2
Sodium silicates	2
Sodium silicofluoride	1
Sodium sulphate (salt cake, etc.)	-2
Sodium sulphide	1
Sodium sulphite	3
Sodium tetraborate (borax)	-1
Sodium thiosulphate	2
Sodium tungstate	-1
Strontium carbonate	-1
Strontium nitrate	0
Strontium sulphate	-1
Sulphur dioxide	0
Sulphur (elemental)	1
Sulphuric acid	1
Tantalum and compounds	3
Tellurium and compounds	1
Thallium and compounds	1
Thorium and compounds	2
Tin and compounds	2
Titanium chlorides	3
Titanium dioxide	2
Titanium metal	2
Tungsten metal powders	-1
Tungstic acid	-1
Tungstic oxides	-1
Uranium and compounds	0
Vanadium oxides	3
Vanadium oxytrichloride	1
Yttrium oxide and derivatives	4
Zeolites and molecular sieves	1
Zinc and zinc ammonium chloride	-2
Zinc oxide	3
Zinc sulphate	-1
Zirconium metal	2
Zirconium oxide	3

The following commentary deals with the highest-rated chemicals and compounds in each group. Subsequent detailed analysis in this study (Section IV) is dedicated to a selection of the chemicals with the highest ratings from this review as well as some other chosen chemicals that were of special interest in the context of Ontario.

Alkali Metals and Derivatives

Though **sodium hydroxide** (caustic soda) shows well in the rating system, it is a co-product of chlorine manufacture so that the two chloralkali products must be considered in tandem. Chlorine does not seem nearly as attractive as caustic soda. **Sodium cyanide** is distinguished by the fact that it is imported in large part from Europe and therefore a candidate for import replacement. Much the same can be said for **sodium bicarbonate**, which is normally made from soda ash (available at Amherstburg, Ontario) but to date has been imported. **Sodium nitrate** deserves consideration because it is also derived from soda ash but is currently being imported.

The two large-volume potassium chemicals—**potassium hydroxide** (caustic potash) and **potassium carbonate**—must be obtained from mined potash, such as is available in Saskatchewan or New Brunswick, but as important as the raw material is the availability of electrical energy. Ontario has one small caustic potash producer at Cornwall, but North America could probably accommodate a larger second supplier to compete with Occidental Chemical. The co-production of chlorine is a complicating factor in the case of caustic potash manufacture.

Table 3.2
Highest ratings for alkali metal derivative

	A	B	C	D	E	F	G	H	Combined rating
Sodium hydroxide	4	1	0	1	0	0	-1	0	5
Sodium cyanide	2	0	2	1	0	0	0	0	5
Sodium bicarbonate	2	2	-1	2	0	0	0	0	5
Potassium hydroxide	3	0	2	1	0	0	-1	0	5
Potassium carbonate	3	1	1	0	0	0	0	0	5
Sodium nitrite	2	0	1	1	0	0	0	0	4
Sodium metal	2	2	-1	1	0	0	0	0	3

Alkaline Earth Compounds

The most interesting commodity areas among the limestone derivatives would seem to be **calcium carbonate** itself (if the material is ground finely enough or reconstituted in precipitated form) as well as **calcium carbide** one of the largest-volume products obtained over the decades via the formation of quicklime. The comminuted calcium carbonate has great promise as a filler in paper products (replacing some kaolin clays) and in plastics. The improved outlook for calcium carbide relates in part to its new role in steelmaking. In the long term, the rising cost of hydrocarbons may once again make calcium carbide an economic source of acetylene for the manufacture of bulk organic chemicals. **Calcium oxide** has a multitude of applications beyond its status as the precursor to calcium carbide. **Calcium metal** currently manufactured at Haley, Ontario, may rate higher if is used more widely as a reducing agent (as in non-ferrite magnets) or one of the existing world producers of the metal chooses to withdraw as a supplier.

Among the magnesium chemicals, the one group exhibiting the most market growth is the organometallics. Ethyl Corp. does not make **alkylmagnesium** catalysts at Sarnia although it does so in the U.S. The continuing expansion of production capacity in linear polyethylene offers opportunities for these catalysts. **Magnesium sulphate** should make inroads in the wood-pulping industry if and when oxygen displaces some of chlorine in the bleachery. (Magnesium sulphate is a buffering agent in oxygen bleaching as well as in the treatment of groundwood pulps with hydrogen peroxide). **Magnesium chloride** manufacture is dependent on the increased production of magnesium metal via the electrolytic route. With magnesium plants slated for Quebec and Alberta, there may be over-capacity for some years to come.

Table 3.3
Highest ratings for alkaline earth derivatives

	A	B	C	D	E	F	G	H	Combined rating
Calcium carbide	4	0	0	1	0	0	0	0	5
Calcium carbonate	4	0	1	1	0	0	-1	0	4
Magnesium alkyls,	6	0	0	0	-1	-1	0	0	4
Calcium oxide, hydroxide	4	0	0	0	0	0	-1	0	3
Calcium metal	3	2	-2	0	0	0	0	0	3
Magnesium oxide (magnesia)	4	0	-1	0	0	0	0	0	3
Magnesium sulphate	2	2	-1	0	0	0	0	0	3
Magnesium chloride	4	0	-1	0	0	0	0	0	3

Aluminum, Silicon and Boron Compounds

Canada's paper industry is a very large importer of coating as well as filler grades of kaolin. In fact, there is a very large regional market for kaolin open to any new producer in the northeastern part of North America, because the only economic source at present is located in the state of Georgia. Another filler/pigment material that could gain greater acceptance in

the paper, coatings and plastics industries is finely-ground **aluminum trihydrate** (ATH). ATH must compete against calcium carbonate and kaolin as an extender pigment. Additional ATH is consumed in the manufacture of the **organoaluminum catalysts**, which are already manufactured in Ontario but should be in even greater demand as the production of polyolefins increases over the next decade. **Sodium aluminate** consumption will continue to rise but much of the increase is due to growing applications for **synthetic zeolites**. There is excess capacity in zeolites as a result of their lack of success in household detergents.

Silicon metal usage in silicone resins and in semi-conductor manufacture will expand steadily. Another high-value outlet for silica is open for what can be converted to colloidal forms (silica gels and sols).

Sodium borohydride deserves attention because it has an expanding role in the bleaching of groundwood pulps. All sodium borohydride in Canada is now supplied from one source operating two U.S. plants.

Table 3.4
Highest rated aluminum, silicon, boron derivatives

	A	B	C	D	E	F	G	H	Combined rating
Kaolin	3	0	1	-1	0	0	1	0	4
Aluminum trihydrate	3	1	1	0	0	-1	0	0	4
Aluminum alkyls	5	0	-1	1	-1	0	0	0	4
Sodium aluminate	4	0	0	0	0	0	0	0	4
Silicon metal	3	2	-1	1	-1	0	0	0	4
Silica gels/sols	4	1	0	0	-1	0	0	0	4
Sodium borohydride	3	1	-1	0	-1	0	1	0	3

Phosphorus Compounds

Few phosphorus compounds have shown much activity in the past ten years or more. The cutback in the use of phosphates in laundry detergents is the most obvious example of retrenchment, but there have also been setbacks in the pesticide and polymeric fields.

Table 3.5
Highest ratings for phosphorus and derivatives

	A	B	C	D	E	F	G	H	Combined rating
Sodium phosphates	2	0	-1	1	0	0	0	0	2
Phosphorus pentasulphide	2	1	-1	0	0	0	0	0	2
Phosphorus pentoxide	2	1	-1	0	0	0	0	0	2

Sulphur Compounds

The manufacture of **sodium hydrosulphite** in Canada has yet to be undertaken, despite the needs of the country's wood pulping industry and the existence of a raw material (sodium formate) in Alberta. The production of **sodium sulphite**, **sodium metabisulphite** and **sodium thiosulphate** has elsewhere been associated with the operation of a soda ash plant, but such has still to happen in Canada.

Table 3.6
Highest ratings for sulphur and derivatives

	A	B	C	D	E	F	G	H	Combined rating
Sodium bisulphites	3	0	1	1	0	0	0	0	5
Sodium sulphite	2	0	0	1	0	0	0	0	3
Sodium thiosulphate	3	0	-1	0	0	0	0	0	2
Sodium hydrosulphide	3	0	-1	0	0	0	0	0	2

Halogen Compounds

Sodium chlorate rates highly as an investment opportunity, because environmental considerations are promoting the use of salt to make chlorine dioxide in the paper mill bleachery as a partial replacement for elemental chlorine. **Sodium chlorite** is another route to the evolution of chlorine dioxide and is being used more extensively by municipalities throughout North America to disinfect potable water. **Calcium bromide** attracts interest because of its growing use in the oil and gas-well drilling industry for high-density, solids-free completion, packer and workover fluids. The lack of bromine deposits in Ontario is a negative factor.

Table 3.7
Highest ratings for halogens and derivatives

	A	B	C	D	E	F	G	H	Combined rating
Sodium chlorate	5	0	0	1	0	0	0	0	6
Sodium chlorite	4	0	-1	1	0	0	0	0	4
Calcium bromide	5	0	0	-2	0	0	0	0	3

Alloying Metal Compounds

Vanadium oxides are recovered mainly because of their existing metallurgical applications, but there is also market potential for vanadium compounds in catalysis and, down the road, in superconducting systems. **Beryllium oxide and alloys** have unique properties that promise very rapid growth in market demand, albeit starting from a small base. **Tantalum** has established applications in electronics, aerospace and chemical equipment manufacture, the limiting factor often being supply and the concomitant high price.

Table 3.8
Highest ratings for alloying metals and derivatives

	A	B	C	D	E	F	G	H	Combined rating
Vanadium oxides	5	1	0	-1	-1	-1	0	0	3
Beryllium oxide	3	2	-1	0	0	-1	0	0	3
Tantalum and compounds	3	2	0	0	-1	-1	0	0	3

Consumption of chromium and manganese ores has always been substantial because of their metallurgical end-uses, but no economic deposits exist in Canada. Imports of chromium and manganese compounds are correspondingly high. Niobium (columbium), tungsten and molybdenum are mined in Canada with the concentrate being exported to countries where extensive metallurgical operations exist.

Titanium, Zirconium, Hafnium Compounds

Titanium tetrachloride is the precursor of titanium dioxide made by the chloride process, of titanium metal and of aluminum alkyl catalyst. There is sizable production of **titanium dioxide** in Canada, but imports are still quite substantial. Some titanium tetrachloride will be manufactured in Quebec for captive purposes and more investment in this area can be anticipated. On the other hand, no titanium metal is likely to be made in Canada for some time to come. Synthetic **zirconium oxide** is required in large volumes for the refractory, abrasives and ceramics industries and **zirconium metal** is the structural material of choice in most nuclear-reactor cores. It has been the demand for "electronic-grade" zirconia in the past few years that has spurred consumption rates in North America. To date the source materials, zircon sand and baddeleyite, have had to be imported—the baddeleyite originates from South Africa.

Table 3.9
Highest ratings for titanium, zirconium and derivatives

	A	B	C	D	E	F	G	H	Combined rating
Titanium chlorides	5	0	-2	0	0	0	0	0	3
Zirconium oxide	3	1	-1	1	0	-1	0	0	3
Titanium dioxide	2	0	0	0	0	0	0	0	2
Titanium metal	2	2	-2	0	0	0	0	0	2
Zirconium metal	2	2	-2	1	0	-1	0	0	2

Antimony, Arsenic, Bismuth Compounds

Easily the most important commercial compound in this group is **antimony oxide**, the popular flame retardant in many plastics. Canada has an operating antimony mine plus by-product antimony available from base-metal smelters. All antimony oxide, however, is imported to date. Certain **arsenic compounds** are also produced in Canada, although demand for arsenics generally has been diminishing over the years. There is also some bismuth recovered in Canada, but the material is not refined in this country. Moreover, market applications are minor and not expanding to any noticeable degree.

Table 3.10
Highest ratings for antimony, arsenic, bismuth and derivatives

	A	B	C	D	E	F	G	H	Combined rating
Antimony oxides	3	0	-1	0	0	-1	0	0	1
Arsenic metal	1	2	-1	0	0	-1	0	0	1

Rare Metal Compounds

Germanium is a substrate for the epitaxial deposition of **gallium** arsenide/gallium arsenide phosphide in a range of semiconductors. Germanium can also be the substrate material for solar cells, and it is gaining acceptance in the field of infrared optics. **Cesium** and **rubidium** have great promise as electropositive elements in magnetohydrodynamics. **Selenium** is a key material in xerography. The demand for **indium** will increase sharply as a result of its efficacy in automotive windshield systems.

The limiting factor is that most of these elements, being relatively rare in nature, are normally produced as part of much larger base-metal mining or smelting operations. Cesium and

rubidium are an exception in this regard, with the Bernic Lake property in Manitoba and its unmatched deposits of lepidolite and pollucite.

Table 3.11
Highest ratings for high-tech rare metals

	A	B	C	D	E	F	G	H	Combined rating
Germanium and compounds	7	2	0	0	-2	-1	0	0	6
Gallium and compounds	7	2	0	0	-2	-1	0	0	6
Cesium and compounds	2	2	0	1	0	0	0	0	5
Rubidium and compounds	2	2	0	1	0	0	0	0	5
Indium and compounds	6	2	0	0	-2	-1	0	0	5

Iron, Nickel and Cobalt Compounds

Nickel compounds will continue to be vital in the manufacture of certain catalysts because of nickel's ability to chemisorb hydrogen. Moreover, black nickel oxide enhances the activity of other catalysts containing rhodium, platinum and palladium. Nickel salts are essential in the electroplating industry, because decorative nickel-plating is used extensively for automobile bumpers and trim, appliances, wire products, flatware, jewelry and many other consumer items. From the point of view of longer-term interest, the use of nickel oxide cathodes has been demonstrated for the conversion of synthesis gas and the generation of electricity in fuel cells.

Cobalt, like nickel, is an important alloying material with increasing application in metallurgy and electronics. The demand for **cobalt compounds** is less certain, although there is growing demand for catalysts based on the presence of cobalt. Cobalt metal is also the base material for the cobalt 60 radioisotope formed in nuclear reactors.

Table 3.12
Highest ratings for other base-metal derivatives

	A	B	C	D	E	F	G	H	Combined rating
Nickel oxides	3	1	0	1	0	-1	0	0	4
Nickel sulphate	3	1	0	1	0	-1	0	0	4
Nickel chloride	3	1	0	1	0	-1	0	0	4
Cobalt oxides	3	2	0	1	-1	-1	0	0	4
Iron sulphates	3	0	0	1	0	-1	0	0	3

Other Base Metal Compounds

Canada's status as a world supplier of base metals puts it in good stead for the production of compounds derived from these metals. The country has its own facilities for making zinc oxide, copper sulphate and various lead chemicals. Yet a surprising number of copper, zinc and other base-metal chemicals are imported. **Zinc oxide** has the greatest export potential because of its versatility and the availability of basic zinc in this country.

Table 3.13
Highest ratings for other base-metal derivatives

	A	B	C	D	E	F	G	H	Combined rating
Zinc oxide	2	0	1	1	0	-1	0	0	3
Tin and compounds	2	1	0	0	0	-1	0	0	2

Precious Metal Compounds

Canada is a source of most, if not all, of the precious metals used around the world. These precious metals are mined for their own sake, as in the case of gold and silver, or recovered as part of base-metal operations. The country hosts two precious-metal refineries for gold and silver, which reduces the volume of imports. Furthermore, many of the platinum group products (catalysts, etc.) are not fabricated in Canada. Of the platinum group compounds, those of **rhodium** would appear to have the most promise, as relatively expensive rhodium is a necessary component of automotive muffler catalysts because of its efficacy in controlling nitrogen oxide emissions.

Table 3.14
Highest ratings for precious metal derivatives

	A	B	C	D	E	F	G	H	Combined rating
Rhodium and compounds	4	1	0	0	-1	-1	0	0	3

Actinides and Compounds

Imports of actinide derivatives have been minimal. In the past a notable non-nuclear application for **thorium nitrate** has been in the Welsbach mantle, but otherwise there is little demand for thorium nitrate.

Table 3.15
Highest ratings for actinides and derivatives

	A	B	C	D	E	F	G	H	Combined rating
Thorium and compounds	1	2	0	0	0	-1	0	0	2

Rare Earth Oxides and Compounds

The recovery of **yttrium oxide**, as distinct from concentrates, allows Denison to participate in the high-value portion of the rare earths business. The plant, which is jointly owned with Unocal Canada, Molycorp, Shin-Etsu Chemical and Mitsui, is capable of supplying a third of the world's requirements for yttrium oxide. Yttrium oxide has much promise in refractory ceramics as well as in TV screens.

The purification of other rare earths—notably **samarium** or **neodymium** for permanent magnets, **gadolinium** for computer devices, **cerium** for glassmaking, **europium** for TV screens—is likely to be an increasingly important activity. Demand for mixed rare-earth oxides, in contrast, does not match available supply.

Table 3.16
Highest ratings for rare earth oxides

	A	B	C	D	E	F	G	H	Combined rating
Gadolinium and derivatives	6	2	0	0	-1	-1	0	0	6
Samarium and derivatives	5	2	0	0	-1	-1	0	0	5
Neodymium and derivatives	4	2	0	0	-1	-1	0	0	4
Europium oxide and derivatives	4	2	0	0	-1	-1	0	0	4
Yttrium oxide and derivatives	4	2	0	0	-1	-1	0	0	4
Lanthanum and derivatives	3	1	0	0	0	-1	0	0	3
Cerium oxide and derivatives	3	1	0	0	0	-1	0	0	3

Highest-Rated Inorganic Chemicals

There are 32 different products or product groupings that were assigned four or more points in the combined ratings. In some cases, products with lower ratings deserve special attention if they are associated with one rated more highly. Thus the prospects for chlorine cannot be separated from the consideration of caustic soda or caustic potash. Similarly, products such as ammonium chloride would look more attractive if an investment were made in the production of sodium sulphite.

Table 3.17
Chemicals with Highest Combined Ratings

	A	B	C	D	E	F	G	H	Combined rating
Sodium chlorate	5	0	0	1	0	0	0	0	6
Germanium and compounds	7	2	0	0	-2	-1	0	0	6
Gallium and compounds	7	2	0	0	-2	-1	0	0	6
Gadolinium and derivatives	6	2	0	0	-1	-1	0	0	6
Sodium hydroxide	4	1	0	1	0	0	-1	0	5
Sodium cyanide	2	0	2	1	0	0	0	0	5
Sodium bicarbonate	2	2	-1	2	0	0	0	0	5
Potassium hydroxide	3	0	2	1	0	0	-1	0	5
Potassium carbonate	3	1	1	0	0	0	0	0	5
Sodium bisulphites	3	0	1	1	0	0	0	0	5
Cesium and compounds	2	2	0	1	0	0	0	0	5
Rubidium and compounds	2	2	0	1	0	0	0	0	5
Samarium and derivatives	5	2	0	0	-1	-1	0	0	5
Indium and compounds	6	2	0	0	-2	-1	0	0	5
Calcium carbide	4	0	0	1	0	0	0	0	5
Calcium carbonate	4	0	0	1	0	0	-1	0	4
Magnesium alkyls, Grignard reagents	6	0	0	0	-1	-1	0	0	4
Sodium nitrite	2	0	1	1	0	0	0	0	4
Sodium chlorite	4	0	-1	1	0	0	0	0	4
Kaolin	3	0	1	-1	0	0	1	0	4
Aluminum trihydrate	3	1	1	0	0	-1	0	0	4
Aluminum alkyls	5	0	-1	1	-1	0	0	0	4
Sodium aluminate	4	0	0	0	0	0	0	0	4
Silicon metal	3	2	-1	1	-1	0	0	0	4
Silica gels/sols	4	1	0	0	-1	0	0	0	4
Nickel oxides	3	1	0	1	0	-1	0	0	4
Nickel sulphate	3	1	0	1	0	-1	0	0	4
Nickel chloride	3	1	0	1	0	-1	0	0	4
Cobalt oxides	3	2	0	1	-1	-1	0	0	4
Neodymium and derivatives	4	2	0	0	-1	-1	0	0	4
Europium oxide and derivatives	4	2	0	0	-1	-1	0	0	4
Yttrium oxide and derivatives	4	2	0	0	-1	-1	0	0	4

4. Assessment of Individual Chemicals

Selection for Assessment

A total of thirty chemicals were selected for analysis of their development potential in Ontario. The majority of the chosen chemicals emerged with the highest combined rankings in a preliminary general review by Law, Sigurdson & Associates. Some chemicals were included in the short list on the basis of possible interest from an Ontario viewpoint in their regional potential. The study of these short-listed chemicals and the subsequent detailed evaluation of the screened potential opportunities were conducted by Law, Sigurdson & Associates and SRI International. The selected chemicals are listed as follows:

- Alumina Trihydrate
- Barium chemicals*
- Calcium carbonate*
- Calcium carbide
- Fluorine/Hydrofluoric acid*
- Magnesium chloride
- Magnesium carbonate
- Sodium bicarbonate
- Sodium chlorate
- Sodium chlorite
- Sodium cyanide*
- Calcium cyanide*
- Sodium hydroxide
- Potassium carbonate
- Potassium hydroxide
- Sodium metabisulphite
- Sodium nitrite
- Silica gels/sols*
- Silicon
- Sodium aluminate
- Titanium dioxide
- Rare Earths:
  - Europium oxide and derivatives
  - Gadolinium and compounds
  - Neodymium and compounds
  - Rubidium and compounds
  - Samarium oxide and derivatives
- Yttrium oxide and derivatives
- Cesium and compounds
- Gallium and compounds
- Germanium and compounds

* covered in Section 5

The chemicals were examined on a continental basis to assess:

1. market growth potential;
2. technical market change;
3. production technology change;
4. fit with Ontario regional markets or resources.

Data gathered on the 30 selected chemicals provided a basis for identifying potential opportunities in inorganic chemicals manufacturing in Ontario. Six of the 30 individual chemicals named at the beginning of this section are treated in detail in Section 5.

Alumina Trihydrate

(aluminum hydrate, aluminum hydroxide)

Over 90 per cent of the alumina trihydrate ($Al_2O_3.3H_2O$) consumed in North America is calcined and subsequently used in the manufacture of aluminum. Alumina trihydrate (ATH) that is not used in aluminum manufacture may be either calcined to produce specialty calcines (such as tabular or fused alumina), activated, or used directly in the hydrated form.

Alumina produced by electric furnace is used by the abrasives (grit) and refractories market, but not used for the production of specialty aluminas.

The United States is a large producer of specialty aluminas sold in the hydrated form. Canada does not yet produce specialty aluminas. The major use of ATH is as a precursor to other aluminum-based chemicals, such as sodium aluminate and aluminum fluoride. Another major use for ATH is as a flame retardant. Comparatively minor quantities of ATH are used as a pigment or filler in paint, rubber and plastics.

Market information

In 1987, 635 kt of ATH valued at $(U.S.)135 million were shipped by U.S. producers, at an average unit shipment value of $213/tonne. 1987 U.S. imports of 29 kt equaled exports. Canadian demand for ATH is significantly less (non-abrasive and refractory applications) and estimated at close to 4 kt.

Table 4.1
Non-Aluminum Alumina Trihydrate: U.S. Consumption

	1987	1993	Average Annual Growth Rate (%)
	(kt)		
Flame retardants	95	125	4.5
Paper filler	25	25	-
Sodium aluminate	140	157	2.0
Miscellaneous alumina chemicals*	375	423	2.0
Total	**635**	**730**	**2.3**

* includes: Aluminum sulphate (from ATH), Fused alumina, Anhydrous aluminum chloride, Aluminum acetate, Aluminum bromide, Aluminum borate, Aluminum diformate, Aluminum triformate, Aluminum oleate, Aluminum palmitate

Since Canada does not make specialty aluminas, it is largely excluded from some ATH markets, such as fire retardant markets, paper fillers, or aluminum chloride (from ATH). Additionally, there is not a large merchant sodium aluminate market for catalyst production in Canada. Major Canadian markets for fine ATH are flame retardants, paper filler, sodium aluminate and synthetic marble. These markets are proportionately smaller than their counterparts in the U.S., for differing reasons:

(a) catalyst production in Canada is at a much lower level, so sodium aluminate and fused alumina are not in high demand;
(b) there is less fine paper (more newsprint) production in Canada;
(c) the level of marketing and technical service offered by the suppliers is relatively low.

Canada currently has no domestic producer of fine ATH, but Alcan plans to become a producer by late 1989 at a plant at Jonquiere, Quebec with annual capacity of 50 kt. Canadian imports of all types of ATH were about 13 kt annually in 1987 and 1988 (includes abrasive grit and refractory brick ATH), mainly from the U.S., with a 1988 value of about $8 million. Canadian exports of ATH, made by Alcan at Jonquiere, were about 14.8 kt in 1988, worth $3.7 million; almost all went to the U.S.

Flame retardant uses of ATH in plastics is the biggest non-aluminum ATH outlet in Canada. Demand is growing well, aided by ATH's property of not generating fumes when heated. Paper filler usage is concentrated largely in eastern Canada, notably Ontario and Quebec. Growth has been good as a result of expansion of fine paper capacity and high prices for titanium dioxide. Demand could experience a significant boost, if suppliers market more aggressively and as ATH becomes more widely accepted in fast-growing production of groundwood specialties. However, fine paper mills that convert to neutral/alkaline papermaking are unlikely candidates for ATH growth. Such mills are opting for calcium carbonate filler.

Producers of sodium aluminate buy the material for plants at LaPrairie, Quebec and Vancouver, British Columbia (both operated by Handy Chemicals) and at Burlington, Ontario and Edmonton, Alberta (Alchem). Demand for aluminate among pulp and paper mills currently exhibits no real growth. ATH is also used in minor but growing quantities by Canadian producers of synthetic marble and onyx.

Table 4.2
Canadian Non-Aluminum Alumina Trihydrate Consumption

	1987	1993
	(kt)	
Flame retardants	3.5	5.0
Paper filler	1.3	3.5
Synthetic marble	0.4	0.5
Sodium aluminate	2.0	2.0
Total	**7.2**	**11.0**

(excl. low quality refractory and abrasive grades)

In North America, among the non-aluminum ATH applications expected to show good growth is the application for flame retardants. Consumption of ATH in flame retardants has been projected to grow at an average annual rate of at least 4.5 per cent in the 1986-1993 period because of the increasing emphasis in this market on halogen-free formulations. Demand as a paper filler is expected to remain flat in the U.S. or even decline, due to competition from talc, calcium carbonate and titanium dioxide pigment. In Canada, more fine paper

production will result in increased demand. In chemical markets, sodium aluminate is projected to grow at an average annual rate of two to three per cent.

Producers

ATH producers use most output captively to manufacture aluminum but also have merchant sales to non-aluminum users. In addition to these companies, Ormet Corporation produces ATH for captive consumption in aluminum production.

Table 4.3
Bayer Process ATH Producers in North America

Company	Location
Aluminum Company of America	Bauxite, Arizona Point Comfort, Texas
KaiserTech Ltd.	Baton Rouge, Louisiana Gramercy, Louisiana
Reynolds Metals Co.	Corpus Christi, Texas
Alcan Aluminum Ltd.	Jonquiere, Quebec

Technology

Alumina trihydrate is produced by the Bayer process, in which bauxite is leached with sodium hydroxide at elevated temperature and pressure. The resulting sodium aluminate solution is then separated and the ATH precipitated out.

Business dynamics

Companies basic in ATH can supply any market. Those who are not basic tend to concentrate on supplying the flame retardant and filler markets rather than supplying ATH as a chemical raw material. These non-basic producers of specialty ATH products include Solem Industries, a subsidiary of J.M. Huber Corp. and the major players in ATH specialities, Great Lakes Mineral Co., and LaRoche Chemicals.

Ontario position

Due to increased demand for aluminum, ATH from the Bayer process is currently in short supply in the United States. Over the long term, the aluminum industry is likely to move to countries in areas located near raw material resources, such as Australia, or regions with comparatively inexpensive electricity, e.g. Quebec, where the alumina can be more economically converted to aluminum. In Canada, Alcan will be able to make up to 50 kt/year of ATH when its new Jonquiere, Quebec plant comes on stream at the end of 1989. With the integrated position of Alcan in the alumina business and no economically feasible bauxite source in Ontario, the potential role of Ontario in the alumina market is limited. Consideration could be given to many of the lower-volume alumina chemical derivatives. Some of these derivatives are integrated businesses of primary aluminum producers.

Calcium Carbide

Calcium carbide (CaC_2) is used as a precursor for a small number of organic chemicals, although it is primarily used for the production of acetylene and as a process chemical in metallurgy. Since the 1970s, markets for calcium carbide have steadily decreased as substitutes have displaced calcium carbide-based chemicals.

Market information

North American consumption of calcium carbide was of the order of 300 kt in 1987. At an average list price of $(Cdn.)500/tonne, total market value was approximately $(Cdn.)150 million. The U.S. demand was two-thirds of the total tonnage and Canada consumed nearly 100 kt.

The most significant market for calcium carbide is as an intermediate in the production of acetylene fuel for metal welding and cutting. Such acetylenic chemicals as acetylenic alcohols and Reppe-process chemicals are produced from calcium carbide. Calcium carbide is also used in desulphurizing and deoxidizing metals, primarily steels. The outlook for U.S. consumption of calcium carbide is for a decline in the use in acetylene chemicals and no growth elsewhere.

Table 4.4
U.S. Consumption of Calcium Carbide

	1987 (kt)	1993 (kt)	Average Annual Growth Rate (%)
Acetylene production	105	95	-2
Acetylene chemicals	45	45	0
Desulphurization	50	53	1
Total	**200**	**193**	**-1**

In 1971 U.S. calcium carbide consumption totaled 645 kt, declining to 255 kt by 1981 and to 200 kt in 1987. Material competition from hydrocarbon-derived acetylene has displaced or eliminated calcium carbide from many of its traditional markets.

Table 4.5
Canadian Supply/Demand for Calcium Carbide

	1987 (kt)	1993 (kt)	Average Annual Growth Rate (%)
Capacity	140	140	-
Production	110	115	2
Demand			
Acetylene, desulphurization	65	65	0
Acetylene chemicals	30	35	2
Exports	15	15	-
Total Demand	**110**	**115**	**2**

In Canada, chemicals production is the most dynamic market for calcium carbide. Cyanamid Canada produces calcium cyanamide, a precursor for hydrogen cyanamide and dicyanamide. These products can be processed to make epoxy resin additives, fire retardants, herbicide, fungicide and pharmaceutical products. Nearly 10 per cent of calcium carbide output goes into the manufacture of calcium cyanide.

Trade

Nearly 10 per cent of the calcium carbide consumed in the U.S. is imported from Canada.

Producers

North American producers of calcium carbide have declined in number over the past decade and those remaining have integrated into downstream derivative markets.

Table 4.6
North American Calcium Carbide Producers

Company	Location	Total Capacity (kt)
Carbon-Graphite Group Inc.*	Kentucky	200
Elkem-American Carbide Co.	Ohio, Oklahoma	140
Cyanamid Canada	Ontario	140
Shawbec Inc.	Quebec	Closed
Total		**480**

* Sole U.S. producer of acetylene from calcium carbide for acetylene chemical production.

Technology

The production of calcium carbide is accomplished by heating calcium oxide (from limestone ore) with coke in an electric arc furnace at temperatures in excess of 1,600 °C.

Business dynamics

The North American business in calcium carbide is declining in its traditional uses as an acetylenic chemical precursor. Consumption in metallurgical uses has increased modestly with the recent upturn in North American steel production, but by no means sufficiently to compensate for market erosion in acetylenics. Current North American capacity is ample.

Success factors

Low electrical energy costs and inexpensive raw material supply are key to this very mature industry. Existing capacity seems adequate to supply regional markets.

Ontario position

We do not see a position for additional plant capacity in the calcium carbide business. Cyanamid Canada once had six furnaces but now only operates two, albeit larger units. It is likely that additional demand would be served from incremental capacity increases by the established producer.

Magnesium Chloride

Magnesium chloride ($MgCl_2$) is used primarily as raw material in the production of magnesium metal. In addition, small amounts are used as a cement additive, in textiles, fireproofing, papermaking, ceramics, and as an intermediate in the production of magnesium oleate.

Market information

By far the largest use of magnesium chloride is in magnesium metal production, consumption in the U.S. alone totalling 127 kt in 1987. However, this market sector is not available to merchant suppliers, since magnesium metal manufacturers produce magnesium chloride internally. This end-use would warrant further investigation only if it were feasible to build an integrated magnesium metal plant in Ontario. Such a project is unrealistic, given existing plans to add major new magnesium metal capacity in Quebec and Alberta.

One-third of U.S. magnesium chloride consumption in applications other than metals production is served by imports. Demand for imported material will grow significantly following Dow's decision, announced in January 1989, to withdraw as a U.S. domestic supplier of magnesium chloride dihydrate prills.

Excluding 34 per cent liquid magnesium chloride, which is still manufactured by Dow at Freeport, Texas, the U.S. market for solid magnesium chloride in either flake or prill form is estimated to be 21 kt.

Canada imported 4 kt of magnesium chloride in 1987, a significant reduction from 1986, when imports totalled 10.5 kt. The decline was due to the substitution of magnesium chloride with calcium chloride in road-spraying applications.

Magnesium chloride consumption patterns in the U.S. and Canada show under 30 kt of product divided among five or six applications.

Table 4.7
Estimated Magnesium Chloride Use in North America

	1988 (kt)
United States	
Flake	8.5 *
Prill	12.5
Canada	
Herbicides/pesticides	0.3
Fining agent	0.4
Road spray	8.0 **
Miscellaneous	0.2
Total	**29.9**

* solid
** solution

Magnesium chloride is currently priced at about 29-33 U.S. cents per kg (13-15 cents/lb.) on average for various products. Prices differ between the flake and the prill product, with flake selling in the neighborhood of $254 per metric tonne and prill in the range of $400 per metric tonne. Canadian imports had a value of $200 per metric tonne in 1987, reflecting a heavy component of low-priced solution.

The market outlook for magnesium chloride in North America is poor, a reflection of environmental and economic pressures. For example, the pulp and paper industry is cutting back on the use of magnesium chloride. Its use as a make-up additive to magnesium bisulphite in kraft papermaking plants is threatened by new environmental control on effluent discharges. Similarly, its use in the production of printing and writing papers is diminishing due to a shift from acid to alkaline sizing for economic and paper quality reasons.

The continuing decline of the tobacco industry in Canada and the consequent reduced demand for herbicides has imperilled another use for magnesium chloride. As previously noted, substitution of magnesium chloride with calcium chloride in road-spraying for dust control will undoubtedly continue. Use of magnesium chloride in the production of oxychloride construction cements is common in Europe, but it has not been adopted to any degree in North America and there is unlikely to be any change.

One of the few magnesium chloride applications with modest growth potential is in the production of magnesium oleate. This chemical is employed as a constituent in varnish driers, dry-cleaning solvents, as an emulsifying agent and a plasticizer lubricant.

Producers

The U.S. market for magnesium chloride is supplied by two domestic producers—Dow Chemical and Great Salt Lake Minerals and Chemicals Corp.—and by imports from West Germany. Dow's production is only in the form of 34 per cent magnesium chloride solution, a product of its Freeport, Texas magnesium metal operations; with a rated capacity of around 96 kt of magnesium, all of which derives from magnesium chloride electrolysis. Great Salt Lake Minerals recovers numerous inorganic salts from brines in Utah.

Kali & Saltz AG, West Germany, ships about 7 kt/year to the U.S. market via Potash Import and Chemical Corporation, New York.

Table 4.8
Magnesium Chloride Suppliers to North America

Dow Chemical	Freeport, Texas
Great Lake Salt Minerals	Salt Lake City, Utah
Kali & Saltz AG	West Germany

Technology

No technology changes are anticipated in magnesium chloride manufacturing. Existing processes are: brine extraction by progressive precipitation and crystallization, seawater extraction, and underground mining of inorganic salts (as practiced in West and East Germany).

Business dynamics

With the exit of Dow from magnesium chloride prill markets, there remains only one U.S. prill producer (Great Salt Lake Minerals and Chemicals Corp.) in competition with a German importer (Kali & Saltz) for the high-price end of the market. It is a market that represents little tonnage and unexciting growth prospects.

Penetration of magnesium chloride markets in North America would appear attractive only if low-cost brine or underground reserves were available that would lower manufacturing costs by assigning most of the cost to co-products (e.g., magnesium hydroxide, calcium chloride, bromine, etc.).

Opportunities for Ontario

Magnesium chloride does not present an attractive manufacturing opportunity for Ontario. The two planned Canadian magnesium metal plants—in Quebec and Alberta—are potential suppliers of magnesium chloride by-product and are therefore in a position to pre-empt market entry by others.

Magnesium Carbonate

(natural, mined ore)

Magnesite is a naturally-occurring mineral composed of magnesium carbonate ($MgCO_3$). The magnesite ore is used as raw material in the production of dead-burned or caustic calcined magnesia (MgO), which has numerous industrial applications (e.g., refractories, animal feeds, agricultural additive, oil desulphurization, chemicals, etc.). Small amounts of crude magnesite are used as fillers, as an agricultural additive and for the preparation of some chemicals, such as Epsom salts. The major end-use of magnesia, however, continues to be in refractories.

Market information

The use of magnesite ore in the production of magnesia has declined as new technologies utilizing sea and lake brines have been adopted. In 1987, only 11 per cent of U.S. magnesia production of 1,000 kt came from magnesite ore ($MgCO_3$).

The two principal magnesite markets are: (1) the production of dead-burned magnesia, primarily for refractory use, and (2) the production of caustic calcined magnesia for numerous industrial end uses. Refractory use, the largest market, has stagnated over much of the 1980s, strengthening somewhat with the recent revival in the fortunes of the steel industry in North America.

In addition to its principal markets, magnesite is used as an additive in the insulation of boilers and pipes, as a filler in rubber, pigments, and paints, as a coating material to prevent the caking of table salt and in the preparation of various chemicals and fertilizers. In most of these uses, however, it is caustic calcined magnesia that is used in preference to crude or synthetic magnesite.

Producers

In 1987, less than 100 kt of magnesite ore was mined in the U.S. The sole U.S. producer of magnesia from magnesite is Combustion Engineering, Inc., located in Gabbs, Nevada. Historically, Canada has increased production of magnesite significantly in the recent past, currently accounting for well over 100 kt.

Should magnesium production ventures in Quebec and Alberta succeed, considerable additional potential markets for magnesite would open in Canada. Ontario is known to have magnesite deposits which could potentially serve the growing Canadian market. However, a key consideration is whether these deposits contain magnesite of sufficient quality to compete with other domestic deposits.

Technology

Magnesite ore ($MgCO_3$) can be treated in two ways. Heating to temperatures above 2,600°F results in refractory grade material called dead-burned magnesia. Heated to temperatures up to 1,600°F results in caustic-calcined material which has a variety of industrial and agricultural uses.

A new process for magnesium metal production from magnesite is being tested in Calgary, Alberta. If successful, this process would be cheaper than the current process of electrolysis of magnesium chloride from sea and lake brines. Reportedly, this new plant will rely on local magnesite deposits that are of appropriate grade and quality.

Business dynamics

The extraction of magnesite for its various industrial applications is little more than a mining operation. The business of "magnesite" is in reality the business of the end-use, either the manufacture of dead-burned or fused magnesia for magnesia refractories, the manufacture of caustic calcined magnesia for filler, chemical or other applications, or the manufacture of magnesium metal.

In the majority of applications of caustic-calcined magnesia, sea-water extraction is a highly competitive process with relatively low-cost material which tends to dominate North American markets. Magnesium metal production normally requires that the source of magnesium (sea-water magnesia, brines or magnesite) be dedicated to serve the needs of metals production. It is only in the case of refractory applications where the unique composition of a magnesite deposit, its absence of impurities or its physical properties can create a market by displacing other magnesite suppliers of lesser quality. However, even there, long-term supply relationships between producers and consumers, plus integrated operations, pose problems of market access.

Success factors

Unless long-term supply arrangements can be obtained for metal producers or for the manufacture of caustic-calcined magnesia, the principal market for a new magnesite production unit would be refractories. Magnesite ore quality and properties would be crucial. Success in refractories markets hinges on an ability to deliver a consistent product, to deliver it at low cost, and to deliver it regularly. These are general attributes of successful mining operations.

Ontario position

Ontario has some interesting magnesite deposits. An increase in demand for magnesium coupled with a competitive magnesium source or production process could lead to an opportunity for Ontario as a raw materials supplier, intermediate producer, or as a producer of finished products. Alternatively, the recovery of the steel industry in North America offers opportunities for a new magnesite producer of quality magnesite for refractory use.

Sodium Bicarbonate

Sodium bicarbonate ($NaHCO_3$) is produced from (or in conjunction with) sodium carbonate. The main use is as a food additive. Other applications include animal feed, manufacture of other chemicals, and cleaning products.

The size of the U.S. market for sodium bicarbonate in 1987 was about 320 kt, with a market value of about $(U.S.)120 million. Demand in Canada is roughly 30 kt, with a value of $(U.S.)10 million.

Table 4.9
North American Use of Sodium Bicarbonate

	1987 (kt)	1993 (kt)	Average Annual Growth Rate (%)
U.S. Demand			
Food Additives	130	135	0-1
Animal Feeds	75	75	—
Chemicals	40	40	—
Cleaning Products	30	30	—
Pharmaceuticals	15	17	2
Fire Extinguishers	10	10	—
Other	20	20	—
Total U.S. demand	**320**	**327**	**0-1**
Estimated Canadian demand	**30**	**31**	**0-1**
Total North America	**350**	**357**	**0-1**

Approximately 12 thousand tonnes of sodium bicarbonate are imported by the U.S. annually. The largest supplier is Mexico accounting for 40-50 per cent of import volume. Recently, due to the weakness of the U.S. dollar, imports have been low. U.S. exports are approximately 15-20 thousand tonnes per year. The primary destination of the U.S. exports is Canada.

North American consumption has been stable in recent years and is expected to remain at about the present level into the early 1990s. The major food application, baking, is not growing significantly because of a shift away from sweet desserts such as cakes. Similarly, all other end uses appear to be mature and no significant growth is expected.

Producers

The principal producers of sodium bicarbonate, their locations and plant capacities, are presented below:

Table 4.10
U.S. Producers of Sodium Bicarbonate

Company	Location	Capacity (kt)
Church & Dwight	Green River, Wyoming	180
	Old Fort, Ohio	125
Kerr-McGee	Westend, California	25
Rhone-Poulenc	Chicago Heights, Illinois	65
Riverside Products*	Cartersville, Georgia	25
U.S. Total		**420**

*The company has sold manufacturing technology and customer list to FMC who is now building a 60,000 ton sodium carbonate plant in Green River, Wyoming.

Church & Dwight has a strong position in the fragmented consumer market, with an established presence on many grocery shelves.

Technology

Sodium bicarbonate is produced from trona ore, also known as natural sodium sesquicarbonate ($Na_2CO_3.2H_2O$). Trona is refined into soda ash (Na_2CO_3). Sodium bicarbonate is then precipitated from a saturated soda ash solution with carbon dioxide. In the past, plants producing sodium bicarbonate were often located near sodium carbonate plants, and at Solvay plants, finished bicarbonate production may be an integral part of the production process.

Sodium bicarbonate can also be obtained by solution mining of nahcolite (natural sodium bicarbonate). The method is similar to solution mining of trona (natural sodium carbonate). Pairs of wells are sunk, a warm water solution is pumped down one well, and the dissolved nahcolite solution is pumped up from the other well. The nahcolite is subsequently crystallized from solution. Sodium bicarbonate produced in this manner is reportedly of high purity and lower cost.

Business Dynamics

This is a well established industry with little prospect for significant growth. The U.S. market is largely supplied by domestic producers, with trade playing a very small role. U.S. capacity has increased substantially since 1980. Even with the closure of the third largest plant (Allied Chemical, 100,000 tonnes at Syracuse, New York) in 1986, there is currently a significant overcapacity of sodium bicarbonate in the U.S.

Ontario Position

The consumption of sodium bicarbonate tends to be proportional to population, thus a significant market can be assumed to exist in Ontario and Quebec. Central Canada is also the likely destination for the bulk of the U.S. exports. Thus there may be an opportunity for new capacity/expansion in Ontario.

Sodium Chlorate

Sodium chlorate ($NaClO_3$) is primarily used as an intermediate in the production of chlorine dioxide (ClO_2). Smaller uses are as an intermediate in the production of other chlorates, chlorites, and perchlorates, as a defoliant and industrial herbicide and in processing of uranium ores.

The product is sold either as a solution or on a dry basis, depending on shipping costs from the production point. Solution material contains approximately 26 per cent sodium chlorate on a weight basis; the relatively high water content makes solution material a regional product, limiting cost-effective distribution to about 200 miles overland.

Market information

Estimated size of the North American market in 1987 was 724 kt, with Canadian consumption representing 34 per cent of this total. At an average price of $(U.S.)320-450/tonne, the total market value is approximately $230-325 million in North America.

The U.S. market is expected to grow at an average annual rate of 4-6 per cent, the Canadian market more rapidly at 5-8 per cent. Most of this growth will be fueled by the pulp and paper industry, as pulp mills switch from chlorine bleaching to chlorine dioxide bleaching due to environmental concern over the presence of chlorinated organics in bleach plant effluent. Substitution of chlorine dioxide for chlorine at the 50 per cent level is believed to substantially reduce the production of these contaminants. The move to high chlorine dioxide substitution levels has been a major trend in Canada, particularly in British Columbia, where several fish hatcheries have been closed because of possible dioxin contamination.

Table 4.11
North American Market Outlook for Sodium Chlorate

	1987	1993	Average Annual Growth Rate (%)
	(kt)		
United States			
Pulp and paper bleaching	439	560	4-6
Chlorates, chlorites, perchlorates	27	31	2-3
Mineral processing	2	1	(-2)
Agricultural uses	8	8	
Other	2	2	-
Total U.S.	478	602	4-6
Canada			
Pulp and paper bleaching	234	351	6
Mineral processing	12	16	5
Total Canada	246	367	6
Total North America	**724**	**969**	**5**

Sodium chlorate production capacity in North America increased sharply in the 1970s and early 1980s in response to rising demand created by strong shifts in substitution of chlorate for chlorine in pulp bleaching. A new round of capacity increases is now in progress as chlorine substitution levels in pulp bleaching move ever higher, impelled by more stringent effluent control standards.

Table 4.12
North American Supply/Demand in 1987

	United States	Canada
	(kt)	
Capacity	316	477
Operating rate	87%	91%
Production	262	435
Imports	218	5
Exports	3	194
Consumption	478	246

Because of the high electrical power consumption to make sodium chlorate, most production has moved to lower-cost power areas, the exceptions being production for local or captive consumption, or production in regionally-protected areas such as the northwest and southeast United States. As a result of this shift, Canadian production capacity increased more than over 35 per cent between 1984 and 1988 while U.S. capacity declined. Quebec has become the major producer of sodium chlorate, and Quebec material is shipped to distribution points throughout the eastern half of the continent.

Albright & Wilson is the largest North American producer, followed by Kema Nord/QueNord, Kerr-McGee, PPG, and Occidental/Canadian Occidental. These five producers account for 62 per cent of total North American capacity. The major U.S. producers are tied to specific market positions. Pennwalt supplies the Pacific Northwest, plus a little of Western Canada on occasion. Georgia Pacific and Brunswick produce for captive use, as did American Pacific until its plant was destroyed. Huron Chemical and HO Process are on-site facilities for local mills. KemaNord, Occidental, and Kerr-McGee have regional positions in the merchant market and compete with Canadian imports.

Table 4.13
Canadian Producers of Sodium Chlorate

Company and Plant Location	Capacity (1988, kt)
Albright & Wilson Americas	
Buckingham, Quebec	36
North Vancouver, British Columbia	76
Thunder Bay, Ontario	46
Alby-Olin Ltd.	
Valleyfield, Quebec	50
B.C. Chemicals Ltd.	
Prince George, British Columbia	34
Canadian Occidental Petroleum Ltd.	
Amherstburg, Ontario	54
Brandon, Manitoba	18
Nanaimo, British Columbia	7.5
Squamish, British Columbia	11
PPG Industries Canada Ltd.	
Beauharnois, Quebec	80
QueNord Inc.	
Magog, Quebec	92
St. Anne Chemical Co. Ltd.	
Nackawic, New Brunswick	10
Weyerhaeuser Canada Ltd.	
Saskatoon, Saskatchewan	23
Total	**537.5**

Table 4.14
U.S. Producers of Sodium Chlorate

Company and Plant Location	Capacity (1988, kt)
American Pacific Corporation	
Henderson, Nevada (being rebuilt)	(20)
Brunswick Pulp and Paper Company	
Brunswick, Georgia	30
Georgia-Gulf Corporation	
Plaquemine, Louisiana	27
HO Process Company	
(Huron/Olin joint venture)	
Purdue Hill, Alabama	14
Huron Chemicals of America Inc.	
Riegelwood, North Carolina	20
KemaNord Inc.	
Columbus, Mississippi	40
Kerr-McGee Corporation	
Hamilton, Mississippi	62
Henderson, Nevada	30
Occidental Petroleum Corporation	
Taft, Louisiana	45
Pennwalt Corporation	
Portland, Oregon	24
Tacoma, Washington	24
Total	**316***

* Does not include American Pacific

A number of major expansions of capacity have been announced. In Canada, expansions by Albright & Wilson, Alby-Olin, Canadian Occidental, and QueNord will add almost 30 per cent to Canadian production capacity by the early 1990s. In the United States, the expansion will be much smaller; KemaNord has announced a 36 kt expansion, and Occidental is also considering some expansion at Taft, Louisiana.

Technology

Sodium chlorate is produced by the electrolysis of sodium chloride in a diaphram-less cell. Cell design and technology has shifted over the past ten years from graphite to metal electrodes (typically platinum metal- or platinum metal oxide-clad titanium). This change in electrode material has led to greater current efficiencies and yields. De Nora in Italy and Eltech in Ohio have also developed new cell designs. More sophisticated techniques for cell liquor concentration have improved production costs for major producers as well.

Business dynamics

Electrical power costs, and consequently effective power utilization, are the determining factors in production costs. Canadian plants, with favorable power rates and metal electrodes, have become North America's low-cost producers. This trend will become more pronounced; as Table 4.15 shows, two-thirds of planned new North American capacity will be in Canada.

Demand for sodium chlorate will increase at a rapid pace over the next five to seven years, until the substitution of chlorine with chlorine dioxide at approximately the 50 per cent level has been attained. The installation of oxygen delignification equipment and/or a shift to mechanical from chemical pulping may, however, reduce the requirements for all bleaching agents, including chlorine dioxide. Once the higher levels of chlorate use in chemical pulp bleaching has been achieved, further growth in chlorate use will come only from pulp mill capacity expansions. Thus in the 1990s, profitability of a sodium chlorate producer will hinge on efficient low-cost manufacturing in plants sized to serve regional markets.

Table 4.15
North American Sodium Chlorate Expansions

Company	Location	Added Capacity (kt)	Target Date
Albright & Wilson	Edmonton, Alberta	50	1991
	Buckingham, Quebec	37	1990
	North Vancouver, British Columbia	60	1991
Alby-Olin	Valleyfield, Quebec	56	1990
HO Process	Claiborne, Alabama	2.8	1989
KemaNord	Columbus, Mississippi	40	1990
	Moses Lake, Washington	50	1990s
Kerr-McGee	Hamilton, Mississippi	n/a	1989
Occidental Petroleum	Taft, Louisiana	15	n/a
Canadian Occidental Petroleum	Nanaimo, British Columbia	8	1990
	Brandon, Manitoba	49	1990

Success factors

Factors required for success in this market are a mix of low-cost production capability, pulp and paper industry position and the ability to sell ancillary equipment. For example, Albright & Wilson, the largest producer, has been successful by combining all three elements. It has regional plants in major chemical pulp production regions, markets chlorine dioxide generators and has a strong technical position in the pulp and paper chemicals market. KemaNord has its base in European pulping technology and can serve the market from two major production sites. Occidental Chemical/Canadian Oxy is a commodity producer, supplying both chloralkali products and chlorate to pulp mills.

Ontario position

Ontario has a major pulp and paper industry to provide a market for sodium chlorate production. At this point, Canadian Occidental in Amherstburg and Albright & Wilson in Thunder Bay supply much of the regional market. Pulp mills in northeastern Ontario are serviced from chlorate plants in Quebec.

Salt production in the Sarnia/Goderich area does provide a development position for sodium chlorate in the province. However, power rates are not attractive, and the present producers are capable of serving the province's pulp and paper sector. These producers have the production technology, market position, and interest in expanding to service the regional market needs; there would be little access for a new producer in the province.

Sodium Chlorite

Sodium chlorite ($NaClO_2$) is used primarily as an intermediate in the production of chlorine dioxide (ClO_2). The chlorite serves as a means of transporting the dioxide. Chlorine dioxide has been gaining favor as an alternative to chlorine in the treatment of both potable and industrial water. Sodium chlorite is also used as a textile bleach.

Although sodium chlorite is several times the price of sodium chlorate, production of chlorine dioxide from sodium chlorite uses a simple batch process. If small amounts of chlorine dioxide are needed, especially if only intermittently, it is therefore more cost-effective to use sodium chlorite. A chlorine dioxide generator using sodium chlorite costs $(U.S.)10,000-$15,000 while one using sodium chlorate is $150,000-$200,000.

Market information

The size of the U.S. market is approximately 5.9 kt on a 100 per cent basis. At an average list price of $2.70/kg, the total U.S. market value is about $16 million. The Canadian market of 1 kt is worth another $2.5 million.

Table 4.16
North American Use of Sodium Chlorite

	1987 (kt)	1993 (kt)	Average Annual Growth Rate (%)
United States			
Water treatment	4.1	4.8	3.0
Textile bleaching and other	1.8	1.9	0.7
Total U.S.	5.9	6.7	2.6
Canada	1.0	1.1	2.6

The U.S. market is expected to grow at an average annual rate of 2.6 per cent. Growth will be largely dependent on the substitution of chlorine dioxide for chlorine in water treatment, including potable water (the principal use), industrial process water including that used in the food processing industry, water for oilfield use, and possibly agricultural irrigation water. Growth will be more modest in textile uses. As in the U.S., Canadian sodium chlorite consumption is chiefly in potable water treatment.

Trade

U.S. imports of sodium chlorite are significant. In 1988, 3.4 kt on an "as is" basis (an estimated 2.2 kt on a 100 per cent basis) were imported from Europe. Atochem is responsible for more than half of these imports.

Producers

The sole North American producer of sodium chlorite is Olin Corporation in the U.S. at Niagara Falls, New York. The newly-announced Albright & Wilson 4.5 kt plant in Quebec will double present continental production.

Table 4.17
North American Sodium Chlorite Producers

	Capacity (100% basis) kt
Olin Corporation	
Niagara Falls, New York	4.5
Albright and Wilson Americas	
Buckingham, Quebec	4.5

Technology

Sodium chlorite is produced by first deriving chlorine dioxide from sodium chlorate. The chlorine dioxide is then reacted with sodium hydroxide in the presence of a suitable reducing agent, such as hydrogen peroxide, to form a solution of sodium chlorite. This solution can then be evaporated to a solid, which contains nearly 100 per cent sodium chlorite.

Business dynamics

It is virtually essential for a sodium chlorite producer to be basic in sodium chlorate in order to generate the chlorine dioxide intermediate. Because of safety factors, chlorine dioxide is generally consumed at the site of its production.

Success factors

The ability to compete for customers in the specialty water treatment market, to supply chlorine dioxide generation equipment, and to supply a line of companion biocides are key factors for success in this market. Olin is a major factor in water treatment chemicals, offering chlorine, calcium hypochlorite and chlorinated isocyanurates as a line of companion biocidal products. Albright & Wilson Americas recently acquired Rio Linda Chemical, a sodium chlorite distributor with a patented position in chlorine generation equipment.

Ontario position

The Canadian market for sodium chlorite is still rather small, although reasonable growth is anticipated. Albright & Wilson's production will exceed requirements for domestic consumption. The balance will probably be exported to the United States, presumably as a replacement for European imports. It is doubtful that the market needs another source of sodium chlorite at the present, at least not in eastern Canada.

Sodium Hydroxide

Sodium hydroxide (NaOH, caustic soda) is one of the most important inorganic chemical commodities. All current merchant North American production is by electrolysis of sodium chloride solutions; chlorine is produced as a co-product in the approximate ratio of 1 unit of chlorine to 1.1 of sodium hydroxide.

Sodium hydroxide functions primarily as a neutralization agent. The major North American markets are in chemicals manufacturing and in the pulp and paper industry, where it is used both to treat wood pulp and as a extractive agent after each bleaching phase.

Most sodium hydroxide is sold as a liquid, typically as a 50 per cent by weight product. Smaller amounts of solid sodium hydroxide are also produced in either bead or, less commonly, flake form.

Market information

In 1987, U.S. sodium hydroxide consumption totalled 9.5 million tonnes. Canadian consumption is estimated at 1.5 million tonnes. Caustic prices rose sharply in 1988, with U.S. spot prices in the northeast hitting $500 per short ton, raising the value of North American shipments to $2.5 billion. Long-term contract prices are lower, of course, with co-product contracts (1 tonne chlorine + 1.1 tonnes sodium hydroxide) earning a lower caustic price than caustic-only contracts.

Demand for sodium hydroxide in the U.S. is expected to grow at an average annual rate of 1.4 per cent through 1993. Canadian demand will grow slightly less rapidly, at 1.2 per cent annually over the same period.

Table 4.18
North American Use of Sodium Hydroxide

	1987	1993 (kt)	Average Annual Growth Rate (%)
Pulp and Paper			
United States	2,269	2,409	1.0
Canada	1,000	1,069	1.1
Chemicals Manufacturing			
United States	4,747	5,346	2.0
Canada	347	382	1.6
Cleaning Products			
United States	485	527	1.4
Canada	62	67	1.4
Other Industrial Uses			
United States	1,964	2,005	0.5
Canada	136	140	0.5
Total			
United States	**9,465**	**10,287**	**1.4**
Canada	**1,545**	**1,658**	**1.2**

Production of sodium hydroxide, however, will be limited due to the somewhat lower growth rates for its co-product—chlorine. Chlorine demand through to 1993 is projected to rise 0.8-1.2 per cent/year in the U.S. and 0.5 per cent/year in Canada.

Caustic shortages due to reduced chlorine demand are likely to be resolved by:

- further substitution of sodium carbonate raw material for sodium hydroxide;
- supply-driven disappearance of chlorine for ethylene dichloride production;
- more complete recycling of black liquor, including any that may have been stored in holding ponds, once the growth in pulp and paper production slows. This will reduce make-up caustic demand; and
- some merchant caustic supply via the lime soda process; FMC is planning such a plant in Green River, Wyoming in conjunction with sodium cyanide production.

The pulp and paper industry dominates Canadian demand for sodium hydroxide, accounting for 65 per cent of total caustic consumption versus 24 per cent in the United States. Unlike chlorine, North American demand for caustic in this market is expected to increase, growing approximately 1-1.1 per cent annually through 1993. The expected higher level of substitution of chlorine dioxide for chlorine is expected to result in some savings in caustic usage, but this will be more than offset by increased make-up requirements for caustic.

Approximately 22 per cent of total caustic consumption in Canada is for chemicals production, the largest defined category being that for propylene oxide. This contrasts with 39 per cent for the United States.

Producers

Total sodium hydroxide production capacity in the United States was 11,448 kt and that for Canada was 1,767 kt. Five chloralkali producers control more than 75 per cent of the total North American market. All produce sodium hydroxide primarily for the merchant market, although several do also have captive requirements. Plants tend to be located where their chlorine production can be utilized on-site.

Table 4.19

North American Producers' Caustic Market Shares

Dow Chemical	33%
Occidental	23%
PPG	12%
Olin	6%
C-I-L	3%
Other	23%
Total	**100%**

Although direct chlorine trade is negligible, sodium hydroxide exports are important for both Canada and the United States. World prices for caustic have been relatively firm, with much of the exported material being consumed in offshore alumina production.

Table 4.20

North American Supply/Demand for Sodium Hydroxide, 1987

	U.S.	Canada
	(kt)	
Production	10,420	1,720
Imports	551	185
Net Exports	1,506	360
Apparent Consumption	9,465	1,545

Table 4.21
U.S. Producers of Sodium Hydroxide

Company and Plant Location	Annual Capacity (at December 1988) (kt)
Akzo chemicals, Inc.	
Le Moyne, Alabama	78
Brunswick Pulp & Paper Company	
Brunswick, Georgia	52
Dow Chemical U.S.A.	
Freeport, Texas	2,111
(including Oyster Creek)	(728)
Pittsburg, California	146
Plaquemine, Louisiana	1,155
Formosa Plastics Corporation U.S.A.	
Baton Rouge, Louisiana	198
Fort Howard Paper Corporation	
Green Bay, Wisconsin	9
Muskogee, Oklahoma	5
General Electric Company, Plastics Business Operations	
Burkeville, Alabama	26
Mount Vernon, Indiana	55
Georgia Gulf Corporation	
Plaquemine, Louisiana	425
Georgia-Pacific Corporation, Chemical Division	
Bellingham, Washington	90
The BF Goodrich Company, Chemical Group	
Calvert City, Kentucky	119
LaRoche Chemicals Inc.	
Gramercy, Louisiana	199
LCP Chemicals & Plastics, Inc.	
Acme, N. Carolina	53
Ashtabula, Ohio	KOH *
Brunswick, Georgia	106
Moundsville, W. Virginia	87
Orrington, Maine	80
Syracuse, New York	(91)
Niachlor	
(joint venture of Du Pont and Olin)	
Niagara Falls, New York	220
Occidental Chemical Corporation	
Convent, Louisiana	300
Corpus Christi, Texas	307
Deer Park, Texas	373
Delaware City, Delaware (part KOH))	93
La Porte, Texas	519
Mobile, Alabama	KOH
Muscle Shoals, Alabama	59
Niagara Falls, New York	307
Tacoma, Washington	219
Taft, Louisiana	601
Olin Corporation, Olin Chemicals	
Augusta, Georgia	112
Charleston, Tennessee	253
McIntosh, Alabama	364
Niagara Falls, New York	65
Pennwalt Corporation, Chemicals Group	
Portland, Oregon	150
Tacoma, Washington	90
Pioneer Chlor Alkali Holdings Inc.	
Henderson, Nevada	113
St. Gabriel, Louisiana	176
PPG Industries, Inc., Chemicals Group	
Lake Charles, Louisiana	1,146
Natrium, W. Virginia	363
Vulcan Materials Company	
Geismar, Louisiana	247
Port Edwards, Wisconsin (part KOH)	45
Wichita, Kansas	182
Weyerhaeuser Company	
Longview, Washington	150
Total U.S. capacity	**11,448[a]**

[a] Currently operating; does not include standby capacity
* KOH = Potassium hydroxide

Table 4.22
Canadian Sodium Hydroxide Capacity

Company and Plant Location	Annual Capacity (at June, 1988)
Canadian Pacific Forest Products, Limited	
Dryden, Ontario	24
Canadian Occidental Petroleum Ltd.	
Nanaimo, British Columbia	30
North Vancouver, British Columbia	160
Squamish, British Columbia	71
Canso Chemicals, Ltd.	
Abercrombie Point, Nova Scotia	24
C-I-L Inc.	
Becancour, Quebec	298
Cornwall, Ontario	50
Dalhousie, New Brunswick	33
Dow Chemical Canada Inc.	
Fort Saskatchewan, Alberta	550
Sarnia, Ontario	396
PPG Canada Inc.	
Beauharnois, Quebec	80
St. Anne Chemical Company, Ltd.	
Nackawic, New Brunswick	10
Weyerhauser Canada Ltd.	
Saskatoon Chemicals Ltd., subsidiary	
Saskatoon, Saskatchewan	36
Total Canadian capacity	**1,767**

Technology

There are three main types of electrochemical cells for chloralkali production, all of which electrolyze sodium chloride solution to produce sodium hydroxide with chlorine as a coproduct.

Membrane cells represent the newest type of cell and have the lowest total power requirements (electricity plus steam).

They produce a pure sodium hydroxide and is likely to account for most new chloralkali capacity worldwide. In addition, a number of older diaphragm installations are being retrofitted with membrane cell units. It is necessary to replace the entire cell, not simply replace the diaphragm with a membrane, and new power rectifiers may also be required because membrane cells have higher-current, lower-voltage profiles than do diaphragm cells. However, other ancillary buildings and equipment on the site can be used.

Mercury cells are the oldest type of cell, and have the highest power requirements. Mercury cells produce a purer sodium hydroxide than diaphragm cells. It is not likely that new mercury cell plants will be built, because of the higher power usage and potential threat of mercury contamination. However, many existing plants will continue to operate; there are substantial barriers for exit and the purity of the caustic produced will continue to be desirable until a sufficient membrane capacity is onstream to satisfy this market sector.

Diaphragm cells currently account for about 78 per cent of all North American chloralkali production. This type of cell produces a less pure sodium hydroxide than mercury cell designs and has intermediate power requirements between those of membrane and mercury.

Cell electrodes have been improved over the past fifteen years. The development of dimensionally-stable anodes (typically platinum-group metal-oxide clad titanium) and activated nickel-coated cathodes have improved current efficiencies.

Historically, some sodium hydroxide was produced by the "lime soda" process—the reaction of sodium carbonate with calcium hydroxide to produce sodium hydroxide and calcium carbonate. This route fell into disuse in the 1960s because of the rising demand for chlorine, and all current merchant sodium hydroxide production is via sodium chloride electrolysis, with chlorine produced as a co-product. However, most pulp and paper mills have causticization capacity to regenerate caustic based on the "lime soda" process. FMC uses sodium hydroxide produced from soda ash causticization in its trona solution mining. Current tightness in sodium hydroxide supply has reawakened interest in this process, prompting FMC to plan production of merchant sodium hydroxide production at Green River, Wyoming.

It may be possible to produce sodium hydroxide by sodium carbonate electrolysis. Diamond Shamrock is believed to have done work on this technology. However, because Occidental, which now owns this technology, is fully committed to downstream integration into EDC/VCM, it is unlikely the process will be further developed at this time.

Business dynamics

Most of the major North American producers of sodium hydroxide have either strong continental or world positions in the chloralkali business. In general, they have significant captive requirements for chlorine and are frequently integrated downstream into chlorine derivatives. Chloralkali production is only one facet of their chemical business, and they usually have some ability to provide flexible "sinks" for excess chlorine (or sodium hydroxide) as the demand balance shifts.

Another class of sodium hydroxide producer is either a pulp and paper mill or a caustic producer corporately tied to supplying a specific pulp mill. In these cases, both chlorine and caustic production is consumed captively. The growing technology shift from chlorine to chlorine dioxide in pulp bleaching is likely to cause chlorine/caustic production imbalances for this class of producer.

Chlorine is a very reactive and somewhat hazardous chemical, hence most chloralkali plants are located close to chlorine markets. Co-produced sodium hydroxide poses less of a safety risk, and material not consumed locally is readily shipped to more distant markets.

Ontario position

Approximately 24 per cent of all Canadian, or three per cent of North American sodium hydroxide capacity is located in Ontario. The two Ontario producers are Canadian Pacific Forest Products at Dryden, and Dow at Sarnia. The Canadian Pacific Forest Products plant is small, and is captive for pulp and paper production. Dow's Sarnia plant alone represents 22 per cent of all Canadian capacity. It is integrated downstream into ethylene dichloride/vinyl chloride monomer and into carbon tetrachloride/perchloroethylene. The hydrochloric acid by-product from these downstream products is recycled into further ethylene dichloride production.

Dow can supply most of Ontario's merchant requirements for sodium hydroxide. Production from Quebec producers is also available. It would be difficult for a new chloralkali producer without captive chlorine requirements to compete. Production based on the "lime soda" process would probably not be competitive on a price basis, and would require both experience with the technology and a good raw material source for sodium carbonate.

Potassium Hydroxide

Potassium hydroxide (KOH), or caustic potash, is derived from potassium chloride and is used in a wide variety of industrial applications, including the manufacture of potassium carbonate and other potassium chemicals, soaps and detergents, and fertilizers.

Market information

The size of the U.S. market for potassium hydroxide in 1987 was approximately 235 kt (100 per cent basis). Overall demand is expected to grow at an average annual rate of 2.2 per cent per year for through 1993. The 1988 price for 45 per cent liquid potassium hydroxide was $(U.S.)0.32/kg, yielding sales of approximately $165 million.

Table 4.23
U.S. Consumption of Potassium Hydroxide, 1987

	1987	1993 (kt)	Average Annual Growth Rate (%)
Potassium carbonate and derivatives (a)	47	53	1-3
Other potassium chemicals (b)	59	68	2-3
Potassium phosphates (TKPP)	23	26	1-2
Potassium soaps	23	24	0-1
Liquid fertilizers	23	27	3
Other (c)	60	70	2-3
Total	**235**	**268**	**2.2**

(a) Includes chemicals made from potassium carbonate such as potassium bicarbonate and bisulphite.

(b) Includes potassium borohydride, laurate, titanate, etc,

(c) Other uses include alkaline-electrolyte storage batteries, electroplating, herbicides, greases, catalysts, oxidizers, and medicines.

Most of the markets for potassium hydroxide are relatively mature and are unlikely to be affected by technological change. A few new markets, such as the use of potassium hydroxide to clean coal, are under development. However, none of these new applications are expected to be commercialized in the next five years.

Producers

Occidental Chemical is by far the largest U.S. producer of potassium hydroxide with three plants accounting for 65 per cent of U.S. output.

Table 4.24
North American Producers of Potassium Hydroxide

Company and Plant Location	Annual Capacity (kt, 100% basis)
United States	
LCP Chemicals and Plastics, Inc.	
Ashtabula, Ohio	58
Occidental Chemical Corporation	
Delaware City, Delaware	64
Mobile, Alabama	53
Muscle Shoals, Alabama	124
Olin Corporation	
Niagara Falls, New York	32
JT Baker (sub. Procter & Gamble)	
Phillipsburg, New Jersey	2
Vulcan Materials Company	
Vulcan Chemicals Division	
Port Edwards, Wisconsin	38
Total U.S.	371
Canada	
C-I-L Inc.	
Cornwall, Ontario	11
Total North America	**382**

Trade

U.S. imports of potassium hydroxide totaled 30.3 kt in 1987, while exports were reported as 18.5 kt. Trade in this chemical between the U.S. and Canada is balanced, probably on geographic lines, with Canadian exports to the United States at 6.3 kt in 1988 and Canadian imports from the United States at 5.8 kt.

Technology

Potassium hydroxide is produced by the electrolysis of potassium chloride (potash). All current North American production uses a mercury cell, which produces a higher-purity product than would a diaphragm cell, but which also requires a higher-purity potassium chloride as feedstock. These cells can be used at most plants for the production of either potassium or sodium hydroxide. Major impurities in potassium hydroxide are potassium chloride and potassium carbonate. Potassium hydroxide is available commercially as a 45-50 per cent solution and as a solid in a variety of forms. Manufacturing technology is not expected to change.

Business dynamics

None of the North American potassium hydroxide producers is basic in potassium chloride, but all except Baker are chloralkali producers. Occidental acquired its facilities from Diamond Shamrock in 1986. The two newest entrants in this business, Olin and Vulcan, entered the potassium hydroxide business at a time when caustic soda supply was loose and prices were very low. Sodium hydroxide capacity was converted to potassium hydroxide in hopes of higher margins. Baker's capacity is used to manufacture a small amount of high-purity potassium hydroxide for specialty applications.

Potassium hydroxide does not experience any material competition as such; it is the only product that can be used in its specific end-uses. However, when sodium hydroxide supplies are tight, which they have been lately, potassium hydroxide can be used in some caustic soda markets.

Success factors

Reputation and name recognition are key factors for success in the potassium hydroxide business. Additionally, all major producers are also sodium hydroxide/chlorine producers, and are able to integrate their potassium hydroxide production with the rest of their chloralkali business.

Ontario position

C-I-L is the only Canadian producer of potassium hydroxide, with an 11 kt plant at Cornwall, Ontario. Given the current markets for potassium hydroxide and the projected growth rate, C-I-L can supply current and probable future requirements for much of eastern Canada, including Ontario, as well as parts of the U.S. northeast. Canadian markets too distant from Cornwall are supplied by imports. It is somewhat unlikely that Ontario would be the preferred site for a second potassium hydroxide installation to serve these markets.

Current markets for potassium hydroxide are limited to those which can absorb the substantially higher price of potassium hydroxide relative to sodium hydroxide. Canada has both excellent potash supplies and low-cost power, although transportation costs to many North American markets might be prohibitive. If Canadian potassium hydroxide could be produced at a substantially lower cost than current material, the potential market would increase somewhat, especially in the water treatment and liquid soap sectors, where potassium hydroxide's greater solubility would be an advantage. In addition to low raw material and electric power costs, a new producer would also need an assured "sink" for the chlorine produced as a co-product.

Potassium Carbonate

Potassium carbonate (K_2CO_3) is produced by the reaction of potassium hydroxide with carbon dioxide. It is primarily used in specialty glasses, in the production of potassium chemicals and in a wide variety of other small specialty markets.

Market information

The size of the 1988 market for potassium carbonate was estimated to be 60 kt, with a value of approximately $25-30 million. Growth generally parallels that of the GNP and will average one to three per cent at best for the next several years.

Table 4.25
Consumption of Potassium Carbonate In North America

	1988 (kt)
Television screens and computer monitors	20
Oscilloscopes	15
Photographic developers	6
Other potassium chemicals	6
Other	13
Total	**60**

Canadian imports of potassium carbonate totaled 1.5 kt in 1987, with a value of $(Cdn.)1 million. The volume of imports has not changed in the last seven years.

The largest market for potassium carbonate is in the manufacture of specialty glasses, such as those used in the faceplates of television tubes and computer monitors. The potassium ion serves both as a flux and to balance the sodium ion present (mixed alkali effect), resulting in a low-conductivity glass. Potassium carbonate also serves a similar function in the cathode ray tubes of oscilloscopes.

Other uses are in manufacture of very pure crystal, in photographic developing solutions, and in production of other potassium chemicals such as potassium silicate, bromide, bromates and iodide. Potassium silicate is believed to be the largest-volume chemical produced from potassium carbonate other than the bicarbonate, which is produced in-situ from the unisolated potassium carbonate solution. Potassium carbonate consumption for potassium bicarbonate production is not included in the consumption estimates above.

The "other" market category is quite diverse. One use is as potassium source for a 0-0-30 specialty fertilizer. Another agricultural use is spraying of hay with a potassium carbonate solution to speed drying. Potassium carbonate is used as a source of carbon dioxide in fire extinguishers, in textile dyes and in pharmaceuticals. A minor use is in the manufacture of Dutch chocolate, where it functions as a darkening agent.

Producers

The largest of the three U.S. potassium carbonate producers is Armand Products Company, a joint venture of Occidental and Church & Dwight, with 1987 sales of $25-30 million.

Smaller U.S. producers are LCP Chemicals, which has pilot plant production of potassium carbonate solutions at Ashtabula, Ohio and J.T. Baker at Phillipsburg, New Jersey, a producer of a small amount of reagent-grade material.

Table 4.26
U.S. Producers of Potassium Carbonate

Company and Plant Location	Annual Capacity (kt)
Armand Products Company Muscle Shoals, Alabama	66
LCP Chemicals & Plastics, Inc. Ashtabula, Ohio	Pilot plant only
J. T. Baker Inc., subsidiary Phillipsburg, New Jersey	Minor
Total	**66**

Trade

1987 U.S. imports of potassium carbonate totaled 2.6 kt, all from France and West Germany. U.S. exports of potassium carbonate and bicarbonate combined were reported as 4.4 kt and believed to be mostly the former. Mexico is the largest importer of U.S. potassium carbonate with 42 per cent of the total. Canadian imports from the U.S. amounted to 1.5 kt in 1987.

Technology

Potassium carbonate is produced by the carbonation of potassium hydroxide solutions. Further addition of carbon dioxide produces potassium bicarbonate. The technology is analogous to that developed for the production of sodium carbonate.

Business dynamics

The only major producer of potassium carbonate is Armand Products. Church & Dwight brings significant technical expertise to the joint venture, in that the company dominates the sodium bicarbonate business. Occidental Chemical brings additional knowledge of the chemical marketplace. In contrast, LCP and Baker have very minor positions. The stated purpose of the joint venture, Armand Products, was to develop new specialty markets for potassium carbonate. It is a relatively recent large producer in the United States, and its markets have probably not yet been completely defined.

Success factors

Cost-effective manufacturing, a pure product and the ability to develop specialty markets are key factors for success in the potassium carbonate business. As mentioned previously one of the joint venture partners also manufactures sodium bicarbonate, a related product with specialty application in the food area.

Ontario position

Currently, Canada is not a producer of refined potassium carbonate although, as a world-scale source of potash, it could easily become one if industry warranted such production. However, with a very low level of specialty glass production in Ontario and Quebec, opportunity is limited for a local producer. Much of the specialty glass products are made in the U.S. for the North American market. Given the absence of domestic demand, an entry on an Ontario producer's part would be questionable. The Armand plant can probably supply all U.S. requirements and, as the material is somewhat of a specialty product, it is not greatly restricted by freight costs.

Sodium Metabisulphite

The markets for sodium metabisulphite ($Na_2S_2O_5$) include chemical intermediates, pharmaceuticals and food preservatives. Additionally, the pulp and paper industry occasionally uses it as an antichlor to remove excess chlorine from bleached pulps. Sodium bisulphite, the raw material for the metabisulphite, is not a stable compound in solid state so the bisulphite is generally transported in metabisulphite form. Commercial sodium bisulphite consists mainly of solid sodium metabisulphite.

Market information

North American sodium metabisulphite production in 1988 for merchant sales is estimated at 40-50 kt. Since the market is fragmented, information on specific application volumes is difficult to obtain. In addition, many companies using sizable volumes carry out their own production. Producers can take in sulphur dioxide and caustic to carry out the reaction.

At an average price for sodium metabisulphite at approximately $(Cdn.)330/tonne, it indicates an overall market value of about $(Cdn.)13 million. Pharmaceuticals take 10-20 kt; chemical intermediates consume 10-20 kt; food preservatives use 5-10 kt. Due to concerns regarding consumer health, substitutes for sodium bisulphite in food are being actively sought. As a result, growth in this market is not expected to exceed one per cent annually.

None of the identified end-uses for sodium metabisulphite will generate much market growth. An emerging application with some growth potential is in the removal of cyanide from effluent streams in gold processing.

Trade

U.S. trade in sodium bisulphite is small and not reported as a separate category. Sodium sulphite, bisulphite, metabisulphite and thiosulphate are combined in import/export statistics. Imports in this combination category are insignificant, while exports total a modest 30 kt.

There is no merchant sodium metabisulphite production in Canada. Distributors specific to the application markets as well as the large chemical distributors handle the business of importing into the country.

Table 4.27
Canadian Imports of Sodium Metabisulphite

	kt	$ million
1981	2.7	0.7
1982	2.5	0.7
1983	3.0	1.0
1984	3.4	1.3
1985	1.9	0.6
1986	2.7	0.8
1987	4.7	1.5

Sodium sulphite producers have the capability to produce the bisulphite as well as the solid metabisulphite form. Which of the companies carry out production of all three in addition to sodium thiosulphate has not been determined, but the process is not complex and producers can easily synthesize the metabisulphite form.

Producers of sodium metabisulphite are basic in sodium sulphite, which as an industry operates at close to 70 per cent of capacity in the United States. Total sodium sulphite merchant capacity in the U.S. is close to 180 kt, while production is of the order of 130 kt. Only about 30 kt of that volume is required to make the 40 kt of the metabisulphite. There is excess capacity present in the industry.

Table 4.28
U.S. Sodium Bisulphite / Metabisulphite Producers

Company	Location
Calabrian Corporation Chemicals Dept.	Port Neches, Texas
E.I. Du Pont de Nemours Co., Inc. Chemicals and Pigments Dept.	Grasselli, New Jersey
The Henley Group Inc.* General Chemical Corp.	Claymont, Delaware
Hoechst Celanese Corp.* Industrial Chemicals Dept.	Bucks, Alabama Leeds, South Carolina Portsmouth, Virginia
Industrial Chemicals Corp.	Penuelas, Puerto Rico
Olympic Chemical Corp.	Tacoma, Washington
Penzoil Co., Penzoil Products Co. Morco Plant	Dickinson, Texas
PVS Chemicals, Inc. (Illinois), subsidiary	Chicago, Illinois

* These companies are known to produce USP and food grade material

Technology

Sodium bisulphite is made by passing sulphur dioxide through other liquors containing sodium carbonate in solution and soda ash in suspension. The sodium bisulphite is obtained as a suspension, which is removed from the solution by centrifuging. The anhydrous form is actually sodium metabisulphite.

Business dynamics

Very little information is available on this chemical and the capacities of the U.S. producers are not known. The production and sale of merchant sodium metabisulphite is normally integrated into a larger overall chemical business.

Ontario position

There does not appear to be a large merchant market for sodium metabisulphite in Canada, and the North American market is amply supplied by a sodium sulphite industry that operates at close to 70 per cent of capacity. The establishment of sodium sulphite/bisulphite production facilities must be justified in terms of the larger markets, currently being serviced in Canada through captive production in the pulp and paper industry, where much of the product is required. The pulp and paper producers using this chemical agent have traditionally produced the product in-house.

Sodium Nitrite

Sodium nitrite ($NaNO_2$) is used in dye manufacture, meat and food preserving, metal processing, as a corrosion inhibitor, and in the manufacture of rubber processing and other chemicals. It is available in liquid or anhydrous form and in technical, USP, and food grades.

Market information

Little quantitative information is available on sodium nitrite. U.S. demand in 1980 reportedly totalled 55 kt, 51 kt supplied by domestic producers. Domestic production in 1987 is estimated to have been 35-40 kt, while imports amounted to 20 kt. Imports are either very low-priced material or in grades not made in the U.S. Some modest growth in U.S. demand appears to have occurred in the 1980-87 period. Future growth, if any, will probably be similarly modest, given the limited number of end uses.

Canadian imports in 1987 totaled 4.2 kt, with a value of $(Cdn.)1.7 million. The import value of $400/tonne suggests this was USP or food-grade material.

Due to controversy over the presence of nitrosamines in food, the use of nitrites in foods such as cured meats has decreased significantly. Consumption now stands at less than one kt, compared to 10 kt at earlier peak demand. Sodium nitrite volumes going into other end-uses have not been identified. One growing use is in the manufacture of vanillin (artificial vanilla) from phenol. Artificial vanilla accounts for 90 per cent of the U.S. vanilla extract market. Based on the reported import

value of about $(U.S.)160/tonne, the total U.S. market for sodium nitrite has an estimated value of about $(U.S.)10 million.

Producers

The U.S. producers of sodium nitrite include large chemical suppliers as well as divisions of firms in the food and pharmaceutical markets.

Table 4.29
U.S. Sodium Nitrite Producers

Company	Plant Location
Croton Corporation	South Plainfield, New Jersey
E.I. Du Pont de Nemours and Co., Inc. Chemicals and Pigments Department	Gibbstown, New Jersey
The Henley Group Inc.*	
General Chemical Corporation	Syracuse, New York
Procter & Gamble Co.*	
Richardson-Vicks, Inc., subsid.	
J.T. Baker Inc., subsid.	Phillipsburg, New Jersey
G. Frederick Smith Chemical Company	Columbus, Ohio

* These companies offer food and USP grades.

Technology

Sodium nitrite is produced by dissolving nitrogen oxides (derived from ammonia manufacture) in an aqueous alkaline solution of soda ash.

Business dynamics

Market segment and capacities of the domestic producers are not available. U.S. imports have increased significantly since 1980. Since then, U.S. production appears to have dropped by about the same amount as the market for sodium nitrite as a meat and food preservative has declined, i.e. 9 kt. There is probably excess U.S. production capacity.

Silicon Metal

Silicon metal (Si) is used as an alloying material for aluminum, ferrous metals and other metal products. It is also used for the production of silanes and silicon nitride. A small amount of high-purity silicon metal is used in electronic applications, but the value of this material is high. Silanes are subsequently used in the manufacture of silicones and other metallorganic chemicals as well as for production of electronic grade silicon metal. Silicon nitride is a ceramic material used in structural and electronics applications.

Market information

North American demand is close to 200 kt annually, with the size of the U.S. market in 1987 being about 161,000 tonnes. Canadian demand is approximately 35 kt per year.

Table 4.30
U.S. Silicon Supply/Demand

		1987 kt
Production		136
Imports	Canada	11
	Other	22
Domestic consumption		161
Exports		8

With prices ranging from $(U.S.)1.36-1.48/kg for silicon metal to $(U.S.)32-40/kg for electronic grade material, total market value was approximately $(U.S.)325 million (electronic grade $96 million; other $229 million). The specifications and price for electronic-grade material varies considerably by customer and exact end-use. Some uses require purity from mobile ions (Na and K) and metals at the 5-6 nines level, others do not. Oxygen inclusion in polysilicon is a common problem.

U.S. consumption in 1987 was 161,000 tonnes and is expected to grow at an average annual rate of four per cent, with consumption reaching 205,000 tonnes by 1993. The most rapid growth (i.e., 10 per cent/yr.) is forecast for electronic materials. Two of the smallest-volume end uses, silicon nitride and electronic materials, are expected to grow at a 10 per cent annual rate.

Table 4.31
U.S. Demand Pattern on Silicon

	1987 (kt)	1993 (kt)	Average Annual Growth Rate (%)
Silicones and Silanes	77.1	103.3	5
Aluminum	57.0	70.4	3
Other Alloys	9.0	10.7	3
Steel	2.5	2.8	2
Electronic Grade	2.6	4.8	10
Miscellaneous	13.2	17.3	4
Total	**161.4**	**209.3**	**4**

Nearly all of the Canadian consumption of silicon is used for metal alloying. There is a lack of an electronics market, and there are no Canadian silicone producers. Canadian production in Quebec serves the local aluminum producers and excess capacity is exported.

Trade

U.S. market data for silicon in 1987 (excluding electronic-grade silicon) are reported by the U.S. Bureau of Mines and summarized below.

Table 4.32
U.S. Trade Data on Silicon

	Amount (kt)	Value ($U.S. million)
Exports	8.3	106.2
Imports	33.5	74.3
Imports from Canada	10.9	—

Producers

There are nine producers of silicon metal in North America, with three producers in Canada and six in the U.S. Generally the firms supply the industry on a merchant basis, with only Dow Corning being integrated with its own silicones business in the production of silicon.

Table 4.33
Major U.S. Silicon Producers

Company	Location
Aluminum Co. of America, (Northwest Alloys, Inc. subsidiary)	Addy, Washington
Belmont Metals, Inc.	Brooklyn, New York
Dow Corning Corp.	Hemlock, Michigan
Elkem Metals Co.	Alloy, W. Virginia
Globe Metal	Beverly, Ohio Selma, Alabama
SKW Alloys, Inc.	Niagara Falls, New York

Canada has three producers of silicon metal as well as ferrosilicon, serving both domestic and international markets. SKW and Elkem both have U.S. plants as well as international operations, so some of the Canadian output goes to Europe as well as into the U.S.

Table 4.34
Canadian Silicon Producers

Company	Location
Chromasco Div., Timminco	Beauharnois, Chicoutimi, Quebec
Elkem Canada	Beauharnois, Quebec,
SKW Canada Inc.	Becancoeur, Quebec

The Canadian producers of silicon metal also are in the ferrosilicon and ferroalloys business. They have based their operations on low-cost power in Quebec as well as high-quality quartz deposits at Mont Laurier, Quebec. Product made in the Quebec furnaces runs to 75-85 per cent or higher silicon. This material goes into electronics and silicones end-uses in North America and Europe, apart from the regional metal-alloying business.

A valuable derivative of silicon metal is polysilicon, which is used by the electronics industry for growing silicon wafers for integrated circuit manufacture.

Table 4.35
Major U.S. Producers of Electronic Grade Polysilicon

Company	Capacity (tonnes)
Hemlock Semiconductor	2,000
Ethyl Corp.	1,250
Texas Instruments	250
Union Carbide Corp.	1,200
Monsanto (now Huls)	230
Motorola Inc.	100
Total	**5,030**

Technology

Metal-grade silicon is made in electric furnaces by heating silica pebbles with carbon, followed by zone refining. Chemical grades are purified by leaching. This basic production process requires large amounts of electric power, making cheap power a primary determinant of silicon plant location and resultant economics.

Little change is expected within the foreseeable future in the production technologies or use of silicon metal. There are no substitutes for silicon metal in its primary uses. The silicone business is relatively mature, but is expected to grow at steady, moderate rates. The silicon nitride market is expected to grow at perhaps 10 per cent per year, but this is a very small market for silicon.

Business dynamics

The metal-grade silicon market is well-established and fairly stable. Manufacturers typically use some of their production in their own metals operations and market to the relatively small numbers of silane companies and the specialty metals foundries using silicon. Pricing and profitability are believed to be typical of most metals businesses. Import competition is significant, but varies somewhat with changes in monetary exchange rates.

The electronic-grade polysilicon business has become highly competitive with the entry of many companies into the busi-

ness within the past seven years. There are now some 15 producers worldwide and most are losing money. Japan has changed from a net importer of polysilicon to an exporter. Japanese companies have acquired several U.S. polysilicon metal and wafer producers. Wacker, the largest supplier worldwide, has suffered sharply diminished profitability. Monsanto, once the largest U.S. producer of both polysilicon and wafers, recently sold its operations to Huls, of West Germany, after taking losses of over $(U.S.)100 million.

Success factors

The important factors believed to be most important for success in the metal-grade silicon business are:

- Low-cost electrical power
- Sources of moderately high-purity silica pebbles
- Substantial manufacturing capital investment

Success in electronic-grade (polycrystalline) silicon requires:

- A manufacturing process that offers substantial cost and/or high-purity advantages over existing processes
- Low-cost electrical power
- Substantial plant investment
- Perhaps integration into wafer manufacture
- A good understanding of the electronics industry

Ontario position

Ontario may offer opportunities for additional silicon metal production, depending in part on the available price of electricity, but the rate would have to be lower than Quebec's. Such an operation might also be integrated forward to produce silanes. Most of the silanes consumed in Canada are produced in the United States, so a silicone market would have to be carved out in Canada. It should be noted that there are many silicon metal producers elsewhere in the world; Brazil, in particular, is an aggressive supplier based on low-cost hydroelectric power.

The manufacture of electronic grade silicon is not attractive because of very large overcapacity and intense price competition. Installed and announced capacity totals about 18 kt, while worldwide demand is about 6.5 kt and growing at roughly 10 per cent per year. Despite this above-average growth rate projected for semiconductor and solar silicon, the overcapacity problem will depress profitability well into the 1990s.

Sodium Aluminate

Some 50-60 per cent of North American demand for sodium aluminate ($NaAlO_2$) is met by captively-produced product. The largest captive use of sodium aluminate is the manufacture of sodium aluminosilicates, also known as synthetic zeolites, primarily used in detergent manufacture. Sodium aluminate is also manufactured for captive consumption by titanium dioxide (TiO_2) pigment manufacturers, who use sodium aluminate to coat titanium dioxide pigments that will be used in applications where it is important to improve the pigment's resistance to ultraviolet light. Other end-uses traditionally supplied by captively-produced sodium aluminate include the manufacture of FCC catalysts, adsorbents, and alumina catalyst supports.

Market information

The primary markets for merchant sodium aluminate are found in water treatment and the papermaking industry, where sodium aluminate competes with alum. Reported production data include all aluminates produced for sale, but compounds other than sodium aluminate are believed to represent a very small portion of production.

Table 4.36
U.S. Sodium Aluminate Markets

	1987	1993	Average Annual Growth Rate (%)
	(kt)		
Zeolites			
Detergent zeolites	31	36	3
Catalysts (primarily FCC)	10	13	4
Adsorbants/dessicants	10	10	-
Titanium dioxide pigments	42	50	3
Water treatment	60	72	3
Paper			
Other			
Total	**153**	**181**	**3**

1987 U.S. sodium aluminate shipments totaled 67 kt (100 per cent by weight), valued at $(U.S.)23 million, or $344/tonne. These data exclude captive uses, probably amounting to 50-60 per cent of U.S. consumption. U.S. imports of sodium aluminate were 56 tonnes in 1987, primarily from Mexico.

Exports of sodium aluminate are not reported and are believed to be insignificant. Overall demand for sodium aluminates is expected to grow at an average annual rate of two to three per cent over the next five years.

The two markets currently showing good growth are sodium aluminate for titanium dioxide pigments and FCC catalysts. FCC catalysts are projected to grow to due to their crucial role in increasing yields of gasoline and the fact that they must be replaced relatively frequently, compared to those used for other refining processes. Titanium dioxide pigments are projected to grow at an average annual rate of two per cent through 1995.

In detergents, growth is being negatively affected by the overall trend to liquid detergents (zeolites are only used in dry formulations). However, future restrictions on phosphates could result in increased use of zeolites in detergent formulations. Assuming two additional U.S. states impose phosphate

bans as planned, growth in sodium aluminate consumption in detergent zeolite manufacture is projected to grow at an average annual rate of 2.4-4.4 per cent over the 1987-1992 period. In water treatment and paper-making, consumption is expected to remain flat.

Producers

There are some sixteen producers of sodium aluminate in North America, with five of them in Canada generally serving regional markets.

Table 4.37
Canadian Producers of Sodium Aluminate

Company	Location
Handy Chemicals Ltd.	La Prairie, Quebec
Hydor-Tech Ltd.	New Westminster, British Columbia
NL Chem Canada Inc.	Varennes, Quebec
Alchem	Burlington, Ontario
Tioxide	Tracy, Quebec

Table 4.38
U.S. Producers of Sodium Aluminate

Company	Location
Alcoa Coastal Chemicals	Houston, Texas New Johnsonville, Tennessee
American Colloid Company	San Bernardino, California
ARCO Chemical Company	Bakersfield, California Channelview, Texas Sand Springs, Oklahoma
Ciba-Geigy Corporation Hamblet & Hayes Co.	Salem, Massachusetts
Delta Chemical Corporation	Baltimore, Maryland
Delta Chemicals, Inc.	Searsport, Maine
Gowen Chemical Corp.	Roanoke Rapids, N. Carolina
W.R. Grace & Co. Davison Chemical Division	Cincinnati, Ohio Curtis Bay, Maryland Lake Charles, Louisiana
LaRoche Chemicals	Gramercy, Louisiana
Midland Resources, Inc.	St. Louis, Missouri
Nalco Chemical Company	Chicago, Illinois
Southern Ionics Inc.	West Point, Mississippi Pasadena, Texas
United States Aluminate Co.	Ashtabula, Ohio Baltimore, Maryland
Vinings Chemical Co.	Coshohoken, Pennsylvania Gretna, Louisiana Marietta, Ohio

Technology

Sodium aluminate is typically produced by reacting sodium hydroxide with aluminum trihydroxide from the Bayer process. Other sources of aluminum, such as bauxite or even aluminum metal, may also be used. The reaction is straight-forward and anyone with batch equipment should be able to carry out production. Batch sizes are on the order of 2,000-2,500 gallons (12-15,000 kg). There is no Canadian production of dry product, so dry product is imported from Europe or the United States.

Sodium aluminate can easily precipitate from solution if in contact with carbon dioxide (present in air) or at sufficiently low temperatures. There is licensed technology available to stabilize the material, so that it can remain in solution for more than one year. Non-stabilized product can precipitate out of solution in several months.

Stabilizers include sodium gluconate or other "sugar-type" molecules. Other stabilizers exist, but the technology is proprietary. The objective of the additives is to produce an oligomer of the aluminate, such that the matrixed product cannot easily form crystals. Because concentrated solutions of sodium aluminate tend to decompose by precipitation of alumina, commercial aluminate will often contain not only excess caustic but also small quantities of certain organic compounds.

The concentration of sodium aluminate solution can be expressed as equivalent alumina activity. Typically, product is sold as 30-33 per cent active, and with caustic/water content at 50-55 per cent by weight, the solution is very basic at pH 14. The aluminate is typically 45 per cent by weight of the solution. Liquid product can be shipped in bulk truck weighing 20-23 tonnes, or in 310-kg drums. Powdered material is sold in 50-kg bags.

Business dynamics

As more companies pay increased attention to quality control, companies that have traditionally supplied their demand for sodium aluminate with captively-produced product may decide to switch to purchased (merchant) product. This switching of supply source has been the factor influencing recent plant construction. The newest sodium aluminate plants were built in 1988 by a venture between Aluminum Company of America and Coastal Products & Chemicals, Alcoa Coastal Chemicals. The combined capacity of these new plants is 150 kt.

Many of the merchant sodium aluminate producers are also producers of aluminum sulphate. Until Alcoa Coastal entered the business, none were basic in aluminum trihydroxide. In recent years, companies building new plants have often followed a strategy of building them primarily to supply a single user. For example, Southern Ionics' plant in Pasadena, Texas was built primarily to serve Akzo America Inc.'s FCC plant there.

Sodium aluminate is a commodity chemical and cost of raw materials are critical to the economics of production and competitiveness of sources.

In Canada, caustic is purchased from suppliers such as C-I-L, PPG, and Dow Chemical. The caustic, which is shipped at

about 50 per cent concentration, has been rapidly increasing in price due to a shortage of product. Price for caustic quoted by one user is now close to $450/tonne, whereas last year the price was closer to $250/tonne. There is such a shortage of caustic in the Quebec area that customers are on allocation. The other raw material, alumina, is sourced from Alcan and is believed to be non-calcined and sold as a hydrate.

The titanium dioxide and sodium aluminate producers are all well situated to acquire the alumina from nearby Alcan operations.

The supply of sodium aluminate in Canada

The two merchant Canadian suppliers of sodium aluminate have been Handy Chemicals (recently purchased by Domtar Chemicals and subsequently sold to Alcan) and Alchem, whereas the two titanium dioxide producers in the country—NL Chem and Tioxide Canada—have been making aluminate as part of their overall operations at Varennes, Quebec and Tracy, Quebec respectively.

Alchem has been a diminishing force in sodium aluminate, the company making only enough product at Burlington and Edmonton to support declining sales to industrial plants treating water for boiler use.

Imports are negligible (only 109 tonnes in 1987) and seemingly limited to bagged material required to some extent in water treatment. The unit value of imports has declined over the past several years. Market price weakness has been accompanied by rising raw material costs of alumina and caustic soda, the two precursor chemicals, indicating the pressures on producer profitability.

Handy at Laprairie, Quebec makes a stabilized liquid that is 45 per cent total solids and 26 per cent active alumina. Its Handfloc-45 technology is licensed by Hydor-Tech, which does its manufacturing in suburban Vancouver. Distributors import smallish quantities of powdered aluminate.

Alchem makes its aluminate at both the Burlington and Edmonton plants, although the company has on occasion imported aluminate from its U.S. parent (Nalco). Alchem has not been nearly as much a factor in this market as Handy, which can offer the stabilized product.

The market for sodium aluminate in Canada

Sodium aluminate is a mature commercial product with long-established applications. The largest outlet for sodium aluminate in Canada (unlike in the U.S., where zeolite manufacture is substantial) is in the coating of titanium dioxide pigments. The paper industry uses a modicum of sodium aluminate for water treatment and rosin sizing, but demand is very small in comparison to that for aluminum sulphate. Water treatment has been a declining market for some years because of the reduced use of the aluminate in boiler feedwater preparation. It has not yet been possible to identify the precise pharmaceutical applications.

Table 4.39
Total Canadian Demand for Sodium Aluminate (as 45% solution)

	1987	1990
	(kt)	
Pulp-mill water treatment	0.1	0.2
Papermill water treatment	0.5	0.5
Fine-paper sizing	0.2	0.2
Other paper sizing	0.4	0.5
Potable water treatment	0.5	0.5
Nutrient removal wastewater	0.3	0.3
Boilerwater treatment	0.7	0.6
Titanium dioxide	4.5	4.8
Pharmaceuticals	0.6	0.6
Miscellaneous	0.7	0.8
Canadian consumption	**8.5**	**9.0**

Ontario position

Given that consumption in the traditional merchant markets for sodium aluminate (paper and water treatment) is not expected to grow significantly and the fact that there is currently significant overcapacity, we do not see any reasonable entry for an Ontario player. Alchem, which has been supplying the market for some time, is retracting its position based on the outlook of a small market.

Titanium Dioxide

Titanium dioxide (TiO_2) is the largest-volume white pigment material. The primary end-use markets for titanium dioxide pigments are: paint, varnish, and lacquer (50 per cent); paper and paperboard (25 per cent); and plastics (15 per cent). Smaller amounts of titanium dioxide are also used in the production of printing inks, rubber goods, electronic and ceramic chemicals.

Market information

The size of the U.S. market for titanium dioxide in 1987 was approximately 1,100 kt. At an average unit shipment value of $(U.S.)1,631, this represents a total market in excess of $(U.S.)1.8 billion.

The U.S. market for titanium dioxide is expected to grow at an average annual rate of about two per cent. The growth outlook to 1993, by market segment, is summarized in Table 4.40. The fastest-growing segment is likely to be plastics. The major markets for titanium dioxide are mature and unlikely to be affected by technological change. The pigment market requires very pure, coated products to obtain special properties.

Table 4.40
U.S. Market Outlook for Titanium Dioxide

	1987	1993	Average Annual Growth Rate (%)
	(kt)		
Paints	550	585	1
Paper	275	310	2
Plastics	165	220	5
Other	110	125	2
Total	**1,100**	**1,240**	**2**

Approximately 90 kt of titanium dioxide is imported by the U.S. annually. The major importers are Tioxide PLC, Thann et Mulhouse, and NL Chemicals. Canada is a net importer of titania, primarily because the domestic producers do not make all required grades.

Table 4.41
Canadian Titanium Dioxide Supply and Demand, 1987

	(kt)
Production	80-95
Imports	36
Exports	25
Apparent consumption	85
End-use:	%
Paints	57
Paper	15
Plastics	17
Other	11

The three existing Canadian titanium dioxide plants have combined production capacities in excess of Canadian market demand. They export mostly to the U.S. at the present time. Export markets will be essential for the continued success of the Canadian producers.

Producers

Du Pont is a major supplier of titania in North America, with four plants totaling 540 kt of capacity or about half the total. Other major producers include Hanson (SCM), Kemira and Kerr McGee.

Table 4.42
U.S. Titanium Dioxide Producers

Company	Location	Capacity (kt)
Du Pont	New Johnsonville, Tennessee DeLisle, Mississippi Edge Moor, Delaware Antioch, California	540
Hanson (SCM)	Baltimore, Maryland Ashtabula,Ohio	200
Kemira	Savannah, Georgia	100
Kerr McGee	Hamilton, Mississippi	80
U.S. Total Capacity		**920**

Canadian Titanium (NL Industries) has a 40 kt sulphate process plant and a 36 kt chloride process plant at Varennes. The Tioxide plant at Tracy is based on the sulphate process. The two sulphate plants use a high-titania (80% TiO_2) slag as a feed stock. The slag is produced by QIT Fer et Titane at Sorel, Quebec from a low-grade ilmenite ore mineral at Allard Lake, Quebec. The chloride process plant uses as feed rutile ore from Australia or Sierra Leone, a synthetic rutile from the U.S. or Australia and slag from South Africa.

Table 4.43
Canadian Titanium Dioxide Producers

Company	Location	Capacity (kt)
Canadian Titanium, NL Industries	two plants in Varennes, Quebec	76
Tioxide Canada	Tracy, Quebec	40*
Total Canadian Capacity		**116**

* Tioxide Canada plans to expand to 50 kt this year (1989).

Technology

Titanium dioxide is produced from ilmenite ($FeO\text{-}TiO_2$) ores. The U.S. has few primary deposits and imports about 80 per cent of its raw material requirement. There are two current production technologies. The sulphate process, which consumes sulphuric acid, is the only source of the anatase-type pigment, which is used in paper. The chloride process, which uses chlorine, produces a higher-grade product for some applications and less solid waste. Since 1959, all new U.S. plants have been based on the chloride process. Worldwide, the last new plant based on the sulphate process was built in 1974.

Business dynamics

The titanium dioxide industry worldwide is dominated by 10 to 15 major producers, most of whom have plants in more than one country.

Table 4.44
Top International Titanium Dioxide Producers

	No. of plants
Du Pont (U.S.)	4
Tioxide (United Kingdom)	8
SCM Chemicals (U.S.)	7
NL Industries (U.S.)	6
Kemira (Finland)	2
Ishihara (Japan)	3

The companies maintain their dominance of the market by controlling the production technology, particularly the more desirable chloride process.

Table 4.45
Planned Titanium Dioxide Expansions in North America to 1992

	Capacity Addition (kt)
U.S. producers	
Du Pont	123
NL Chemicals	82
Kemira	45
Kerr McGee	48
Canadian producers	
Tioxide Canada	10
Total North America	**308**
Total World	**607**

Planned worldwide expansions in titanium dioxide between 1989 and 1992 will add 607 kt to the existing 3,328 kt of capacity. Nearly half (46 per cent) of the new capacity will be added in Canada and the U.S.

Ontario position

Ontario is unlikely to affect the titanium dioxide market as a basic raw material supplier. Slag from Sorel is a major source of raw material for the sulphate process and would be very difficult to displace. Rutile or synthetic rutile made from ilmenite is the major raw material for the chloride process; only Du Pont is capable of using high-grade ilmenite in its chloride process plants. Excess sulphuric acid production capacity exists in Ontario, raising the possibility of its use for processing imported ilmenite into synthetic rutile. However, the basic economics are dubious. Further additions to the already excess Canadian titanium dioxide capacity would be difficult to justify. Furthermore, only one of the existing major producers could build a new plant since they control the technology. Suitable grades of ilmenite available in the province could provide an Ontario producer of titania with a more attractive raw material position to compete in the regional and global markets.

Rare Earths and Yttrium Oxide

This section reviews markets for four of the fourteen lanthanide series rare earths in the table of periodic elements. It also includes examination of two other metallic chemical elements, rubidium and yttrium, whose production or marketing can be done by the rare earth suppliers. Where the ensuing discussion refers to rare earths as a class, the data includes rubidium and yttrium.

Three metallic chemical elements—cesium, gallium and germanium—have production and trade patterns distinct from those of rare earths and are reviewed in later separate sections.

Market information

The size of the North American market for rare earths in 1987 was estimated to be 17 kt (contained basis) with a market value in the range of $(U.S.)300 million (including concentrates).

Table 4.46
North American Rare Earth Market

	Weight	Value
	%	
Catalysts and Chemicals	35	35
Metallurgical Applications	30	15
Glass and Ceramics	25	15
Specialty Electronic Uses	10	35

Rare earths have historically lost promising markets to less expensive materials. The outlook for U.S. consumption of rare earth materials is shown in the following table.

Table 4.47
North American Demand Outlook on Rare Earth Materials

1987	1993	Average Annual Growth Rate
(kt)		
17	20	3-5%

The North American market for rare earth materials is expected to grow at an average annual rate of three to five per cent. The fastest-growing segment is expected to be in electronic uses such as magnets and superconductors.

From the standpoint of volume, cerium oxide is the most imponant rare earth oxide (REO). It is used in catalysts and for polishing glass. However, it does not command as high a price as the other REOs.

Producers

Most of the U.S. suppliers of rare earth materials are processors only. Listed below are the principal suppliers with location and service provided.

Table 4.48
Rare Earth Producers/Processors

Company	Location	Service
Unocal Corp.		
Molycorp Inc.	California	mining & processing
Rhone-Poulenc	Texas	processing only
W.R. Grace	Tennessee	processing only
Globe Metallurgical Inc.	Ohio	metal products
Reactive Metal & Alloys	Pennsylvania	metal products

The major world sources of rare earths are: a) a large bastnasite deposit at Mountain Pass, California operated by Unocal Corp., b) heavy mineral sands containing monazite, located primarily in Australia, India, and Brazil, and c) a complex bastnasite/iron ore deposit in the People's Republic of China. Minor amounts of xenotime, loparite, and brannerite are being or have been mined for their rare earth content. Loparite is also a source of cesium and rubidium and brannersite can be a source of uranium. Xenotime is a heavy mineral sand found in very low concentrations and recovered in China and Malaysia.

Technology

Bastnasite mined in California comprises 12 per cent of the ore body—a very high concentration, resulting in low processing cost. Bastnasite is in the form of a mixed lanthanide-fluoride-carbonate mineral.

The bastnasite and monazites are composed of 95-99 per cent of the so-called light elements: cerium, lanthanum, praseodymium, neodymium, samarium, and minor amounts of the other rare earth elements. Cerium is the most abundant REO in all these minerals, usually around 50 per cent of the total. Lanthanum and neodymium are next at 15-25 per cent. However, all the REOs are present (except promethium) to some extent. Xenotime is very different, as it contains less than 10 per cent of the light elements, 60 per cent yttrium and 25 per cent of the heavier REOs from europium through lutetium.

Processing entails separation and purification using solvent extraction, ore roasting, and/or ion exchange. The degree of purity (99.99 per cent to 99.9999 per cent) needed for the end-use determines how much processing is necessary.

Molycorp has well-developed technology for processing bastnasite through solvent extraction technology. It also possesses technology for production of high-purity oxides involving vacuum filtration and carefully controlled firing.

Success factors

Success in the marketing of rare earth minerals involves having the production capability and in-depth knowledge of rare earth separation technologies and markets. Being able to produce the complete spectrum of rare earths is also a necessity in competing successfully. A concentrated ore or raw material source is vital to be competitive.

Ontario position

There is some mining of rare earth minerals in Ontario, but no refining capacity in Canada to separate out the individual compounds. Ontario could possibly expand by providing processing facilities for the rare earths currently being produced or that could be produced in the province.

Europium oxides and derivatives

Europium (Eu) and its derivatives are a minor constituent in rare earth minerals. The U.S. market for europium products is estimated to be five tonnes, with an estimated value of $(U.S.)10 million. U.S. suppliers of europium products are Rhone-Poulenc and Unocal. Uses include phosphors for CRT displays, color TV tubes, and fluorescent lamps.

Annual growth is expected to be three to five per cent, spurred by changing technology in electronics, e.g. in phosphors, magnets, and superconductors.

Refining of europium involves ion exchange or solvent extraction from raw ore. Improved separation processes could lower the cost of refining.

New end-uses are developed by highly specialized research firms. Production capability and in-depth knowledge of rare earth separation methods and markets are necessary for success.

Ontario is not a likely supplier of raw material.

Gadolinium and compounds

Gadolinium (Gd) and its compounds are used primarily in electronics. Such uses include gadolinium-iron garnets (GIGs) as ferrite materials in microwave applications and phosphors in TV and computer screens.

The size of the U.S. market is approximately 18 tonnes and the market value about $(U.S.)2-5 million. Average annual growth is expected to be four to eight per cent until 1992. Unique properties of gadolinium materials will make finding substitutes a difficult task. The primary supplier of gadolinium products in the U.S. are Rhone-Poulenc and Unocal..

Neodymium and compounds

Neodymium (Nd) and its compounds are some of the more common rare earth minerals. Major uses are in electronics, including laser beams, capacitors, microwave components, and TV face plates. Neodymium is gaining acceptance as a superior material in permanent magnets.

The size of the U.S. market is 90-450 tonnes with an estimated market value of $(U.S.)10-50 million. Average annual growth rate will be seven to fifteen per cent through 1992. Major U.S. suppliers include Unocal Corp. and Rhone-Poulenc.

Applications include magnets which can use alloys of neodymium and samarium. These magnets have increased power and permanence versus conventional materials.

Rubidium and compounds

Rubidium (Rb) and its compounds are used in either research or commercial applications. Research uses account for 75 per cent of all uses and include direct energy conversion devices, power generators, and solar cells. Among commercial applications are high-voltage rectifying tubes and infra-red lighting. In most applications rubidium is inter-c[illegible]ngeable with cesium.

Market information

The size of the U.S. market in 1983 was 590 kg. Prices in 1986 were as follows:

Rubidium metal:	Rubidium compounds:
tech-grade: $660/kg	tech-grade: $227-246/kg
high-purity: $825/kg	high-purity: $340-374/kg

Estimated average annual growth for rubidium is two to three per cent. Based on this estimate, demand is expected to be 770 kg in 1992, relatively insignificant compared with most mineral and chemical commodities. Because the majority of rubidium is consumed in research applications which have a high degree of uncertainty, commercial application of the element amounts to only 145-160 pounds.

Commercial applications include:

(a) optoelectronics, rubidium being an excellent photoconductive material and easily ionized;

(b) thermoionic applications, because the electron work function of the element is very low, and

(c) various biological applications.

The last, which are similar or occasionally identical to those employing cesium, include separation of viruses and other large organic molecules by centrifuging, as a component of certain sedatives and as biological tracer. However, none of these applications constitutes a volume or tonnage market. The minute market renders them attractive only to specialty chemical producers of ultra-pure compounds for research, medical, or electronic applications.

Producers

The major world source of rubidium ore is a mine located in Canada. The Tantalum Mining Corp. of Canada Ltd., which owns the mine, suspended mining operations in 1982 due to weak markets and large inventories.

Raw rubidium ore (lepidolite) is processed in the U.S. for various end uses. The following table lists known processors.

Table 4.49
Producers of Rubidium and Compounds

Company	Location
Cabot Corporation	Revere, Pennsylvania
Deepwater, Inc.	Carson, California
KaiserTech Ltd.	Solon, Ohio
Morton Thiokol	Danvers, Massachusetts

Technology

Processing of lepidolite ores for their rubidium content is a relatively simple but laborious undertaking. Lepidolite is fused with gypsum and subsequently leached in hot water. Rubidium is subsequently separated from other alkali metals in solution by precipitation in the form of rubidium sulphate and multiple crystallizations.

There is little interest in improving rubidium process technology, since it is unlikely that such innovations would lead to any significant increase in the current low market volumes.

Business dynamics

As in the case of other low-volume, specialty research metals, rubidium producers are few and well-established. Even if a new producer were to gain access to existing specialized market niches, it is questionable that the effort would prove profitable.

Ontario opportunities

The low demand and poor growth prospects for rubidium and rubidium compounds make it an unlikely candidate for Ontario. In any case, were the market outlook to improve significantly, it is probable that Tantalum Mining Corp. would reopen its Bernic Lake rubidium ore production unit.

Samarium oxide and derivatives

Samarium (Sm) and its derivatives are relatively uncommon rare earth materials. The primary application of samarium is in high-performance permanent magnets. Recently, neodymium has shown both performance and cost advantages in this area.

The size of the U.S. market is 65-90 tonnes with a market value of approximately $(U.S.)10-15 million. The average annual growth rate for samarium materials is expected to be five to 10 per cent until 1992. The major U.S. suppliers of samarium materials are Unocal Corp. and Rhone-Poulenc.

Yttrium oxide and derivatives

Yttrium (Y) and its derivatives are used in electronics and ceramics applications. Electronics uses include yttrium-aluminum garnets (YAGs) as host crystals for lasers, yttrium-iron garnets (YIGs) in microwave applications, and yttrium used as a host for computer and TV screen phosphors. Yttrium oxide is used in producing ceramics.

The U.S. market for yttrium products is estimated at 45 tonnes, with a market value of $(U.S.)50 million. Average annual growth is projected at 5 to 10 per cent, leading to a projected demand for yttrium products of 75 tonnes in 1995.

Rhone-Poulenc is the major supplier of yttrium products in the U.S. Imported material also comes from China and Japan.

An abundant raw material supply of xenotime ore is required in the production of yttrium. The raw ore must contain heavy rare earth oxides. Excellent processing technology is also necessary.

In Ontario, Denison Mines, in a joint venture with Molycorp and Sinestsu, extracts an yttrium concentrate from its uranium ore by-products at Elliot Lake. The material is shipped to Molycorp for processing into separated oxides or other derivatives.

Cesium and compounds

Cesium (Cs) and its compounds are used primarily in research and development applications. Examples are research in thermoionics and turboelectrics.

The size of the U.S. market is approximately 11 tonnes with an estimated value of $(U.S.)10-15 million. U.S. cesium pricing in 1986 was as follows:

Cesium metal:	Cesium compounds:
tech-grade: $275/lb.	tech-grade: $37-44/lb.
high-purity: $375/lb.	high-purity: $73-79/lb.

Because of the limited volume of sales, a reflection of cesium's reliance on research, as opposed to industrial markets, the overall market for cesium is estimated at about $10 million, a relatively insignificant quantity by the standards of most mineral and chemical commodities.

Based on the small amount of commercial magnetohydrodynamic research being done, the outlook for growth of cesium markets is poor. This is a change from the outlook for cesium a few years ago, when relatively high oil prices had fostered considerable attention on the development of alternative energy conversion processes, such as magnetohydrodynamics (the direct generation of electric power from hot, ionized combustion gases).

Producers

The major source of cesium ore is a mine in Canada. Tantalum Mining Corp. of Canada Ltd., owner of the mine, suspended operations in 1982 due to weak markets and large inventories.

Raw cesium ore (pollucite) imported from Canada and Zimbabwe is processed in the U.S.

Table 4.50
U.S. Processors of Cesium Ores

Company	Location
Cabot Corp.	Revere, Pennsylvania
Callery Chemical Co.	
Deepwater, Inc.	Carson, California
KaiserTech Ltd.	Solon, Ohio
Olin Corp.	Seward, Illinois
United-Guardian, Inc.	Hauppauge, New York

Technology

Research on commercial applications of cesium have lagged because of prevailing low oil prices. With oil exploration activities languishing because energy prices have moderated, the former urgency of developing alternative, more efficient electricity generation schemes has disappeared. Aggravating this situation for the future market outlook of cesium has been the fact that other elements, such as potassium, can effectively substitute for cesium in many of the thermoionic applications for which cesium appeared to have a niche market position.

In addition to the experimental, and largely stagnant, potential markets for cesium, it is used in minor quantities by the chemical industry and in medicine. For example, it can be used as a fluorination catalyst, in optical crystals, as a component of alkaline storage battery electrolytes, in the desulphurization of heavy oils, as an ingredient in microwave reflectors, as a component of certain cathode X-ray tube phosphors, as a controlled density media for the separation of viruses and other large organic molecules in the laboratory, and in certain military applications. However, in most of these applications required volumes are small and unlikely to increase substantially in the near-term. For example, the relative abundance of good-quality oil at moderate prices reduces demand for heavy oils requiring desulphurization.

Business dynamics

The small industrial market for cesium and the high level of specialization in research and other potential applications makes the business of supplying cesium an uncertain proposition for new producers.

Opportunities for Ontario

The low demand and poor growth prospects for cesium and cesium compounds makes it an unlikely candidate for Ontario. In the improbable event of new industrial uses raising demand, the Tantalum Corp. cesium mine at Bernic Lake in Manitoba would perhaps resume production. The mine was the chief source of pollucite (the cesium mineral) for the U.S. until 1982.

Gallium and Compounds

Gallium is a rare metal primarily recovered as a by-product of alumina production. Gallium metal and compounds (Ga, $Ga(CH_3)_3$, GaAs, et al.) are mainly consumed in the electronics industry. The promise of high growth for gallium arsenide as a semi-conductor substrate has not been realized.

Market information

Total world production in 1987 was 39 tonnes, of which the U.S. consumed an estimated 11 metric tons. Prices for 99.99 per cent pure gallium in 1987 were $(U.S.)350-400/kg, giving a total U.S. market value of about $4 million. U.S. consumption of gallium metal and compounds is projected to grow at an average annual rate of 15 per cent through 1993.

With the exception of the small quantities used in specialty alloys, gallium is used exclusively by the electronics industry. Gallium metal is converted to alkyl compound form (e.g. trimethyl gallium) and most of this is consumed for the synthesis of gallium arsenide or gallium phosphide in single crystal ingot form. Gallium arsenide ingots are sliced into wafers, from which are fabricated light-emitting diodes, integrated circuits, and other electronics components. Trimethyl gallium also is employed as a dopant and epitaxial deposition material in the electronics industry.

Table 4.51
U.S. Consumption of Gallium

	1987	1993 (kg)	Average Annual Growth Rate (%)
Electronics*	8,981	21,900	16
Light-emitting diodes	1,416	2,500	10
Research and Development	268	470	10
Specialty alloys	64	90	6
Total	**10,729**	**24,960**	**15**

* In field effect transistors, laser, semiconductors and other electronic devices.

Producers

There are two classes of producers of unrefined gallium metal in concentrate form, namely primary producers who extract it from bauxite ore during aluminum production and those who produce it from secondary sources, usually scrap. The companies which engage in purification of the unrefined concentrate into high-purity grades of gallium are usually also primary raw gallium producers.

Table 4.52
Primary-Source Raw Gallium Producers

Producer	Country	Capacity Tonnes
Rhone-Poulenc	Australia	50
Rhone-Poulenc	France	20
Sulzer Bros.	U.S.	15
Ingal International	W. Germany	12
Sumitomo Chemical	Japan	10
Alcan Aluminum Canada		4
Others	—	39
Total		**150**

Table 4.53
Secondary-Source Raw Gallium Producers*

Producer	Country	Capacity Tonnes
Alcan Aluminum	Canada	10
Preussag Ag Metal	W. Germany	8
Others	—	32
Total		**50**

* as of December 1988

Rhone-Poulenc dominates the world gallium market and probably accounts for close to half of world output of both unrefined and high-purity material. World gallium purification capacity of 131 metric tons is considerably underutilized at existing demand levels (39 metric tons in 1988).

Table 4.54
Purified Gallium Producers

Producer	Country	Capacity Tonnes
Rhone-Poulenc	U.S.	50
Rhone-Poulenc	France	20
Ingal International	W. Germany	20
Sumitomo Chemical	Japan	10
Alcan Aluminum	Switzerland	10
Cominco	Canada	4
Others	—	17
Total		**131**

Technology

Nearly all gallium currently produced is extracted from bauxite ore in conjunction with alumina production, although gallium also is found in zinc ores. A significant secondary source of gallium is recovery from scrap (i.e. rejected ingots, wafer, or chips). After extraction, gallium metal is refined to a level of four to five nines purity.

The market for gallium in gallium arsenide-based integrated circuits (ICs) has not grown as rapidly as had been predicted in the early 1980s. The primary reasons are continued progress in improving silicon-based ICs, difficulties in producing high-purity uniform gallium arsenide wafers, and fabrication of IC devices from gallium arsenide wafers. While these problems are slowly being overcome, the growth and ultimate size of the gallium market now appears likely to be much smaller than originally expected. Another technological development that has reduced total gallium demand is the deposition of gallium arsenide on silicon wafers, rather than making the wafers of pure gallium arsenide.

Silicon remains the principal competitive material for gallium in the electronics market. While gallium arsenide offers higher circuitry speed and resistance to radiation, it is roughly ten times as expensive as silicon and is likely to remain so.

Business dynamics

Rhone-Poulenc has established a dominant worldwide position in gallium. The widely publicized predictions of rapid growth attracted many companies into the business in the early 1980s. The subsequent failure of the market to develop as forecast has created serious problems for these producers and several are likely to exit the business over the next few years. Sumitomo probably will succeed because of its close ties to the Japanese market.

Some companies are attempting to survive by integrating forward into gallium arsenide wafers, but this effort also is being frustrated by the slow growth of the IC market for gallium arsenide substrate.

Success factors

Success in the gallium metal business will require:

- A low-cost source of raw gallium (i.e. extraction in conjunction with another metal, such as aluminum or zinc).
- A highly efficient extraction and purification process.
- Large capital investment in manufacturing plants.
- Possible, forward integration into gallium arsenide and gallium phosphide wafers in the long-term.
- Strategic alliances with major users of gallium or gallium arsenide to ensure long-term joint product development and supply relationships.

Ontario position

Although Ontario is well positioned in terms of aluminum production, extraction and purification technologies, production of high-purity gallium is not attractive because of enormous world overcapacity (130 metric tons of capacity, versus demand of about 40 metric tons).

Germanium and compounds

Germanium (Ge) is a rare metal recovered as a by-product of base metal production. Germanium has for the most part been displaced by silicon as a semiconductor substrate. Currently, primary uses include infra-red optics (primarily for military uses) and fibre optic systems.

Market information

World demand for germanium was 180 metric tons in 1987, with U.S. demand at 38 metric tons. At prices in the $(U.S.)650-750/kg range, U.S. market value was $(U.S.)27 million.

U.S. demand for germanium is projected to grow at an average annual rate of seven per cent. The primary uses are in infra-red optics and fiber optic systems. Both of these applications are growing slightly faster than the germanium market as a whole. U.S. germanium imports in 1987 totalled six tonnes.

Table 4.55
U.S. Market Outlook for Germanium

	1987	1993 (kg)	Average Annual Growth Rate (%)
Infra-red Optics	24,700	39,200	8
Fiber Optic Systems	6,000	9,500	8
Detectors	1,900	2,700	6
Semiconductors	1,900	2,500	5
Others*	3,500	4,700	5
Total	**38,000**	**58,600**	7

* Incl. catalysts, phosphors,metallurgy, and chemotherapy.

Producers

The sole Canadian supplier of germanium is Cominco in British Columbia.

Table 4.56
Major World Germanium Producers

North American	
Cabot Corp.	Pennsylvania
Eagle-Picher	Oklahoma
Parish Chemical	Utah
Musto Exploration (operations suspended)	Utah
Cominco	Trail, British Columbia
Others	
Metallurgie Hoboken-Overpelt	
Jersey Minière Zinc	
Otavi	
Bleiberger Bergwerks Union	
Pennarroya	
Preussag	

Cabot Corp., a major U.S. inorganic chemical supplier, is the principal germanium player in North America. Eagle-Picher claims to be a major producer and developer of technology and was recently awarded a $(U.S.)3 million contract to provide germanium substrates for gallium arsenide solar cells to the aerospace industry.

Technology

Germanium is recovered in the extraction of copper, zinc and lead ores. It is converted to the tetrachloride, hydrolyzed with water to the oxide, and reduced to the metal with hydrogen. For most applications, it is further zone-refined. For electronics products, germanium is melted and drawn into single-crystal ingots, which are sliced into wafers for device fabrication.

No changes in production technology are anticipated. New electronics applications have emerged and others have disappeared over time; none of these, however, have had a dramatic effect on total demand.

Other metals compete with germanium in various electronics applications. Silicon displaced germanium as a primary material for semiconductor substrates in the late 1950s. In the U.S., lead salts have been adopted in place of germanium as catalysts for plastics resin manufacturing.

Business dynamics

With the diminution of its earlier prominence as an electronic material, germanium has settled into a relatively stable, low-key business. Cabot and Eagle-Picher are major factors in the U.S. market.

Musto Exploration threatened to disrupt the market two years ago by announcing a new mining process and sharply lower prices for germanium. This operation has not proven successful, however, and was shut down at last report.

U.S. government purchases for strategic stockpiling provide the only significant large transactions in the germanium market at this time and no other extraordinary developments in the business are apparent.

Success factors

Success in the germanium business requires:

- Low-cost extraction (in conjunction with other metals)
- Efficient refining and purification
- A moderate amount of joint product development effort with large customers
- Access to the aerospace market

Ontario position

In the light of Cominco's existing production operations and the moderate growth outlook for this metal, opportunities for new producers appear limited.

5. Potential Opportunities in Inorganic Chemicals

The speed of the commercial development process in the chemicals industry is such that few growth opportunities are overlooked by existing producers. Change in production and applications technology, growth in specific use areas, regionalization of markets and product specification changes are factors that can nevertheless provide some entry potential for a new producer of an inorganic chemical. These factors were considered in the evaluation of chemicals and their potential entry opportunity for Ontario industry using industrial minerals.

Five potential opportunities have been identified as being worthy of consideration in the context of this study and possibly further investigation by interested parties. They are as follows:

- barium chemicals
- precipitated calcium carbonate
- colloidal silica
- hydrofluoric acid and/or fluorspar supply
- sodium cyanide

No engineering, costing or raw material suitability evaluation work has been done on these products. Instead the focus has been on the market potential and the potential fit with Ontario, its regional markets and possible raw materials.

Barium Chemicals

Basis for opportunity

Production of barium chemicals in Ontario represents an opportunity based on providing competitive products, replacing imported Far Eastern material as well as European products for the Ontario and Quebec market. In addition, a plant will have to sell into the regional northeast U.S. market, backing out European-, Chinese-, and U.S.-produced material.

The factors for an opportunity in barium chemicals are as follows:

- Regional market—service and transportation;
- Production basic in barite raw material;
- Low cost of other raw materials;
- Outlet for by-products—pulp and paper mills;
- Opportunistic capital acquisition;
- Available technology/experience in barium chemistry.

Barite ore exists in Northern Ontario, and users of the derivative products would be interested in considering a nearby source for their barium chemical requirements. Ore quality will have to be determined to ascertain for which final products the raw material is best suited and/or what preliminary processing of the ore would be needed prior to production of chemicals.

Opportunity in this market is not based on strong market growth, but rather in penetrating markets currently serviced by established suppliers. Service and price competitiveness, based on favorable plant location and transportation advantages, are among the bases for the opportunity.

Table 5.1
Barium Sulphide: First Order Derivatives

Barite ore + Carbon ——> Barium sulphide (captive use)
Barium sulphide + Sodium carbonate ——> Barium carbonate (sales) + Sodium sulphide (sales)
Barium sulphide + Hydrochloric acid ——> Barium chloride (sales)
Barium sulphide + Sodium sulphate ——> Barium sulphate (sales) + Sodium sulphide (sales)

An Ontario-based facility would be well situated to service the Ontario and Quebec markets, which make up nearly all of the Canadian demand for barium chemicals. In addition, it would be well located to service accounts in the northeast portion of the United States. This would include customers in Ohio, Pennsylvania, Michigan, West Virginia and New York. Currently, this market is serviced by the Chemical Products Corp. plant in Cartersville, Georgia, and offshore suppliers.

Entry into the barium chemicals supply industry should be considered as a package involving mining the ore, production of the precursor, barium sulphide, and production of at least two high-volume demand derivatives of barium sulphide—e.g. barium carbonate and barium chloride. Additional secondary or tertiary derivatives, such as the sulphate, hydroxide, titanate, and stearate, can also be considered. These represent value-added areas that the operator may elect to service from the basic position.

Table 5.2
Second and Third Order Derivative Options

Barium carbonate + Titania ——> Barium titanate (low purity)
Barium chloride + Titanium chloride ——> Barium titanate
Barium carbonate + Carbon ——> Barium oxide
Barium oxide + Water ——> Barium hydroxide
Barium oxide + Oxygen + Heat ——> Barium peroxide
Barium carbonate + Nitric acid ——> Barium nitrate
Barium chloride + Sulphuric acid ——> Barium sulphate (medical)

An interesting by-product of the basic reaction for making barium carbonate is sodium sulphide, which can be combined with water to make sodium hydroxide and sodium hydrosulphite. Both chemicals can be used in the pulp and paper industry. The value of by-products such as these, and that of the caustic, improve the economics of the operation.

Markets and Producers

Regional market for barium chemicals

We estimate the regional market for barium chemicals to total 24.6 kt, or $(Cdn.)16 million for all barite chemical derivatives. The total Canadian market of close to 6.7 kt would not cover the production of a reasonably-sized plant, perhaps 20-30 kt, so exports outside this base would have to be considered to cover the plant's output. The northeast regional market offers a more sizable market.

Apart from base barium carbonate and barium chloride production, there are additional opportunities in carrying out further reactions, albeit at low volumes, to achieve value-added products that can serve the regional markets. Examples of downstream barium derivatives include barium hydroxide, high-purity barium chloride, barium titanates, barium ferrites and barium stearates. We have briefly investigated the market for a selected few of these derivatives.

Table 5.3
Canada and Northeastern U.S. Market for Barium Chemicals

	Canada	Northeast U.S. (kt)	Total
Barium carbonate	4.0	10.0	14.0
Barium chloride	1.5	4.0	5.5
Barium hydroxide	0.3	2.7	3.0
Barium sulphate	0.9	1.0	1.9
Miscellaneous	-	0.2	0.2
Total	**6.7**	**17.9**	**24.6**

In addition to the barium chemicals markets, there are nearby markets for by-product sodium sulphide at kraft pulp mills. Derivatives of by-products could also be considered for production and sale—ammonium sulphide and sodium sulphydrate are examples.

Continental market for barium chemicals

Barium sulphide is the raw material for the production of various barium chemicals. The market for barium carbonate and barium chloride represents the bulk of the demand for the sulphide, although it can be sold as a sulphide or made into precipitated barium sulphate. Merchant sulphide customers produce upgraded, value-added, low-volume barium chemicals.

Nearly all of the barium sulphide made by the one remaining North American producer is consumed captively for the production of barium chemicals.

Barium carbonate is the major barium chemical used in North America, employed mostly in the ceramics industry. Barium chloride is a major barium chemical used for the production of barium colorants, and as an ingredient in heat-treating baths, as well as flux in the manufacturing of magnesium metal (depending on process). Barium hydroxide is mostly imported into North America and has a variety of applications.

Table 5.4
North American Demand for Barium Sulphide

	1988 (kt)
Production	25
Demand	
Barium carbonate	15
Barium chloride	5
Precipitated barium sulphate	2
Merchant sales, etc.	3 *
Total	**25**

* Includes merchant sales for barium chloride production.

The market in North America has declined over the last 20 years. In 1969, demand for carbonate was 80 kt per year. Market erosion in TV picture tubes, glass production and ferrites has significantly reduced demand for barium chemicals. The decline seems to have bottomed out and modest growth should be present in the long term.

Producers of Barium chemicals

There now exists only one barium sulphide producer in North America—Chemical Products Corp., with a plant in Cartersville, Georgia. This supplier handles the high-volume heart of the business for barium carbonate and barium chloride. Smaller chemical suppliers use the sulphide and other barium chemicals to make lower-volume, value-added chemicals.

Distributors bring in barium chemicals from offshore sources, with much of the volume sold to "on the coast" customers. All of the Canadian demand is serviced through distributors.

Table 5.5
Identified World Production Facilities

	Number of plants
China	3
Germany	1
Italy	1
United States	1
Spain	1
Total	**7**

Several North American suppliers of barium chemicals have exited from the business as demand in markets declined during the 1970s. Production has shifted from the United States, with increased output from the Far East and Europe.

Table 5.6
Capacity of North American Barium Chemical Producers (Carbonate Capacity Indicated)

	1980 (kt)	1988
Chemical Products, Georgia	15	30
FMC Corp., California	30	-
Sherwin Williams, Kansas	10	-
Total	**55**	**30**

Chemical Products Corp. (CPC) has been the survivor in a declining market, partly since the company is basic in the mining of a high-quality ore and the ability to be in a position to sell their product in non-declining markets, such as brick and glass applications.

CPC operates two kilns, one for strontium chemicals production (mostly carbonate) and the other for barium. The production process for strontium is almost identical, and the markets in glass overlap, so CPC, like other world producers, carries out production of both.

The strontium carbonate capacity for CPC is estimated at 25 kt. Demand is roughly 20 kt per year in North America, with over three-quarters used for TV plate glass production. Being a producer of strontium chemicals, CPC has good economy of scale for the plant site at Cartersville.

FMC Corp. at Modesto, California closed its operations in 1984, and subsequently shipped its unit to Mexico as well as simultaneously selling its technology to the Mexican producer. FMC, on the west coast, fell victim to Chinese imports which penetrated the brick market with low-priced material. The glass and other barium chemical markets in the eastern United States were too far for the company to service, since that market was well supplied by CPC.

Germany-based Kali-Chemie is a major European supplier, which also moves product to North America, servicing the high end of the barium chemicals business. Its prices for barium carbonate are generally higher, commensurate with a higher product quality. This producer claims over 100 kt capacity. It recently expanded its carbonate facilities in Germany and Italy. Kali-Chemie also supplies strontium chemicals from Europe.

Three or four chemical producers play the value-added low-volume, higher purity business that CPC does not serve. Serving a regional or market niche for selected barium products, included are: J.T. Baker at Phillipsburg, New Jersey; Barium And Chemicals and Mallinckrodt Inc.

Barium Carbonate

Markets

Barium carbonate is the primary barium chemical derived from barium sulphide. Its use derives from specific functionality of the molecule. The most important of these characteristics is its ability to precipitate sulphates. A second significant feature is its function as a precursor to barium oxide, which in turn is useful in hardening glasses and ceramics. A third function of barium carbonate is its radiation-filtering properties which are particularly in television picture tube manufacture.

The North American market for barium carbonate is approximately 32 kt, valued at $(Cdn.) 20 million.

Table 5.7
North American Demand for Barium Carbonate

	1988 (kt)
Production	16
Imports	16
Total supply	32
Demand	
Brick and porcelain	15
Specialty glass	5
Electronics	3
Ferrites	3
Sulphate	2
Miscellaneous	2
Total North American domestic demand	30
Exports	2

The most significant end use for barium carbonate is the ceramics market, where barium carbonate is used both in clays to insolubilize sulphates as well as in the glazing and frit compositions as a barium oxide precursor. The barium oxide produced from the thermal degradation of barium carbonate improves the hardness, lustre, physical and chemical resistance of frits.

Barium carbonate is also a chemical precursor for the production of barium ferrites and barium titanate used in ceramic electronic devices such as magnets, dielectric and piezoelectric devices and ceramic capacitors.

Barium carbonate has suffered market erosion due to competition with strontium derivatives, such as strontium carbonate in TV picture tubes and strontium ferrite in permanent magnets. Imports of barium carbonate to the U.S. have increased from two per cent of domestic consumption to 50 per cent since 1971. In 1971 U.S. barium carbonate consumption totaled 61 kt. This total dropped sharply to 31 kt by 1981. Material displacement by strontium analogs is thought to have run its course.

Brick and porcelain demand

Barium carbonate is used to sequester the sulphates that are contained in the clays used for brick manufacture. The volume of barium carbonate employed depends on the sulphates in the clay. Typically, the volume of barium carbonate can be of the order of one to five lbs. per tonne of clay (3 tonnes of clay per 1000 bricks), although for some clays there is no carbonate required. The dosage also depends, in part, on the brick colour.

There is an estimated total annual Canadian and United States clay brick production of six to seven billion units. The barium carbonate volume required by the industry is estimated at 15 kt per year.

Canadian brick demand

In Canada there are four brick producers, with plants strategically located to service regional construction markets. Total volume of barium carbonate used by the Canadian clay brick producers is roughly estimated at 2.5-3 kt per year, with a value of $0.9 million.

The major canadian clay brick producers are as follows:

Canada Brick	Mississauga, Ontario
Brampton Brick Ltd.	Brampton, Ontario
I-XL Industries Inc.	Medicine Hat, Alberta
Shaw, L.E. Ltd.	Lantz, Nova Scotia

Brick plants are generally regionally located near demand centers. Transportation of brick is expensive. In Canada, the major consuming regions are in Ontario and Quebec. With a dozen plants spread across Canada, total capacity of the industry is estimated at 800 million bricks per year.

With the construction boom in the mid-1980s, the brick industry has had a chance to expand. Brampton Brick is finishing a new plant with additional capacity, while shutting down

the old Brampton facility. Canada Brick plans additional capacity in the 1990s in Milton, Ontario. The new plant would be 200 million units per year, which would rationalize smaller existing units for Canada Brick.

United States brick and frit market

Demand for barium carbonate in bricks, floor tiles and roof tiles approaches 11 kt per year. Of that volume, demand in bricks represents approximately 10 kt per year. Usage in glazes and frits account for an additional 1 kt.

Table 5.8
Regional U.S. Barium Carbonate Brick and Frit Market

	1988 (kt)
Northeast	3
Southeast	2
South central	4
West coast	2
Total brick and frit	**11**

Brick production in the United States is slanted toward the Southern states—particularly North and South Carolina, Texas, Georgia and Tennessee, as well as on the west coast.

Table 5.9
Major U.S. Brick Producers

	Number of Plants
U.S. Brick (Division of Canada Brick)	13
General Shale Products	15
Glen/Gery Corp.	14
Acme Brick	16
Boral Brick	20
Total of some major producers	78
Total number of U.S. brick plants 140 (approximately)	

Barium carbonate consumption varies from plant to plant, depending on the sulphate content of the clay deposit from which the bricks are manufactured as well as the color of bricks to be produced. Some clay deposits have a very low level of sulphates, so the use of the carbonate is minimal or zero. Light-colored bricks may hide possible scumming problems as a result of the leaching out of the sulphates, so the usage may also be reduced.

U.S. west coast clay supposedly has significant impurities of sulphates, so the dosage for the carbonate is relatively higher than for eastern plants.

The regional demand pattern for the lower volume required by the frit producers is different from that of the brick manufacture. Frit producers are mostly located in the northeast U.S., and include suppliers which service the sanitaryware business and appliance manufactures.

The operations of Ferro Industrial Products in Oakville, Ontario require carbonate as does the Chi-Vit Corp. plant at Ingersoll, Ontario, although it is estimated the total demand is less than 0.1 kt.

Table 5.10
Major Frit Suppliers in North America

Ferro Industrial Products	Oakville, Ontario
Ferro Corp.	Cleveland, Ohio
Chi-Vit Corp.	Chicago, Illinois
Chi-Vit Corp.	Ingersoll, Ontario
Fusion Ceramics Inc.	Carrollton, Ohio
American Porcelain Enamel Co.	Muskegon, Michigan
Degussa Corp.	Plainfield, New Jersey
Mobay Corp.	Baltimore, Maryland

Barium carbonate for specialty glass

It is estimated that only five kt of barium carbonate is still used in the specialty glass industry. In the 1960s and 1970s this market was in the range of 30 kt per year.

Much of the glass industry is located in the northern United States, where it has established itself as a mature industry. The regional northeast U.S. market could therefore represent three to four kt per year of demand for carbonate. It is the specialty glass producers which have usage for barium carbonate. In specialty optical glass the carbonate is used to obtain a high refractive index. It is also used for glass microspheres in reflective signs.

In the production of television and computer terminal picture tubes, barium carbonate can capture radiation within the tube, minimizing the hazard to viewers. For color tubes this application has been taken over by strontium carbonate, but glass for computer monitors offers some remaining market.

Flat glass and bottle glass producers do not use carbonate, although at one time bottle production did require the material. In efforts to reduce the weight of bottles the heavy barium carbonate lost out.

The North American glass products industry is a $20 billion business. Flat glass, fibre glass, containers and lighting represent 90 per cent of the value of products. Television tubes and cathode ray tubes account for roughly $(Cdn.) 700 million in sales.

Table 5.11
Major Specialty Glass Producers

Zenith Electronics Corp.	Glenview, Illinois
General Electric Co.	Fairfield, Connecticut
GTE Corp.	Stamford, Connecticut
Lukens Inc.	Coatesville, Pennsylvania
BMC Industries Inc.	Minneapolis, Minnesota

Trade

Imports currently represent 40-50 per cent of total domestic North American barium carbonate consumption. China, West Germany, and Brazil are significant exporters to North America. Since 1980 two domestic barium carbonate producers have exited the market, and only one domestic producer remains in business. Inexpensive imports of carbonate put extreme pressure on producers to close operations.

Table 5.12
U.S. Barium Carbonate Imports

	1988 (kt)
China	5.6
Germany	1.0
Italy	0.2
Brazil	0.1
All other	2.7
Total	**9.6**
Total value ($Cdn. million)	**5.8**

China is the principal exporter of barium carbonate to the North American brick market. Chinese material landed in Canada is generally less expensive than German, U.S., and Italian material. Imports of Chinese material into Canada are handled through distributors. Canada imports 100 per cent of its requirements, mostly from China and West Germany. Nearly all of the material is handled and stocked by distributors, with no users buying directly.

Table 5.13
Barium Carbonate Imports to Canada

	1986 ($000)	1986 (kt)
Ontario	425	1.2
Quebec	661	1.9
Other	271	1.0
Total	**1357**	**4.1**

Specifications and prices

There exist slight differences in product quality between U.S., Chinese and European material, so companies in the high-volume brick business buy low-priced Chinese material if the quality is not a problem. Occasionally it is the case with some brick producers experiencing problems with dispersion, which relates to particle size and contaminants. West German material is used, even though it is more expensive, in these cases.

Table 5.14
Barium Carbonate Specification

	Typical Brick Specification
Barium carbonate	98.0% min.
Barium sulphides	0.5% max.
Other sulphides	0.1% max.
Insolubles in HCl	0.4% max.
Iron	0.004% max.
Calcium oxide	0.3% max.
Magnesium oxide	0.1% max.
Silica	0.3% max.
Barium chlorides	trace
Barium hydroxides	trace
Particle size (mesh)	200-325

All of the purchases of barium carbonate for the brick industry is handled through distributors in Canada. The price of material though these distributors is $550-600 per tonne. Chinese material is less expensive than the European product. German carbonate sells in Canada for $800 per tonne.

Imported German material is considered of higher purity, sells at the top end of the market and therefore finds applications in glass and barium titanate production.

Chemical Products Corp. quotes the list price in the United States at $(Cdn.)740/mt FOB plant in bags, truckload quantities.

Barium Chloride

Markets

We have estimated that the barium chloride demand in North America is in the order of 10 kt per year, valued at close to $(Cdn.)6 million per year.

Table 5.15
North American Barium Chloride Demand

	1988 (kt)
Organic pigments	5
Barium titanates	2
Miscellaneous, chemicals	2
Uranium production	1
Total demand	10
Canadian/Northeastern U.S. market	6-7

The regional market in Ontario, Quebec and northeastern United States is approximatly six to seven kt per year. Many of the organic dye producers are located in the northeastern U.S. Major dye producers such as BASF, Ciba Geigy, ICI, and Bayer would use the product.

Tam Ceramics and Transelco both located in New York State, use an estimated total of one kt for the production of titanates. Chemical Products Corp. services these accounts with dihydrate material. An additional one kt of barium chloride may be used by other titanate producers in the U.S., but most of this demand is in the Carolinas and the west coast, near the CPC Georgia plant.

Canada has historically imported between one and two kt of barium chloride per year. Most of the volume is purchased for use in uranium production. Rio Algom and Denison at Elliot Lake represent a regional market for an Ontario producer. Radium is co-precipitated with the barium salt to form radium barium sulphate.

There is not significant production of barium titanates or dyes requiring barium in Canada, so the dominant barium chloride demand comes from the uranium producers.

Producers

North American Producers of barium chloride are:

- Barium & Chemicals — Steubenville, Ohio
- Chemical Products Corp. — Cartersville, Georgia
- J.T. Baker — Phillipsburg, New Jersey
- Mallinckrodt Inc. — St. Louis, Missouri

Chemical Products Corp. (CPC) is the major producer of barium chloride in North America, although smaller producers include J.T. Baker, Barium Chemicals and Mallinkrodt, which can occasionally make product on order. CPC manufactures in Cartersville, Georgia, being integrated to the barium sulphide production there. CPC sells barium sulphide to the other producers which make low-volume, higher-purity products.

We estimate that CPC produces six kt per year of barium chloride while the other domestic suppliers make two kt per year.

Imports

Nearly 20 per cent of the barium chloride consumed in North America is imported. Major exporting countries include China, Spain and France. Some 1.5 kt comes into Canada, while 2.1 kt is brought into the U.S.

Table 5.16
U.S. Barium Chloride Imports

	1988 (kt)
China	0.7
Spain	0.5
France	0.4
Germany	0.1
All other	0.4
Total	2.1
Total value ($Cdn. million)	0.8
Total 1987 Canadian imports	1.5 kt
Import value ($ Cdn. million)	0.5

Barium chloride price differences are based largely on purity considerations, a similar situation to that of barium carbonate. Chinese material comes into Canada at less than 400 $(Cdn.)/tonne, while U.S. material quoted from CPC sells for 684-840 $(Cdn.)/tonne. German material is generally the most expensive.

Table 5.17
Identified Prices for Barium Chloride (FOB plant truckload volumes)

	$(Cdn.)/mt
Dihydrate 15% water	684
Anhydrous	840

The value of imports into Canada from China averaged approximately $(Cdn.)310 per tonne in 1987. These may be sold by distributors at marked-up values, closer to $400 /tonne.

Barium Hydroxide

Markets

The most significant market for barium hydroxide is in the production of lubrication oils and greases, where it is used in the form of a salt of nonylphenol or sulphonate in performance -additive compositions. Barium hydroxide is also used in the barium saccharate process for conversion of sugar cane molasses into cane sugar. This industry has seen the impact of conversion of much of the commercial sweetener business to beet sugar and, more recently, to various corn sweeteners. Barium hydroxide is also a chemical precursor for the production of polyvinyl chloride heat stabilizers.

Total North American demand is estimated at six kt, valued at close to $(Cdn.)7 million.

Table 5.18
North American Barium Hydroxide Consumption

	1988 (kt)
Lubricating oil/Grease	3
Stabilizers	2
Barium saccharate	1
Total	**6**

Barium hydroxide has suffered market erosion in several markets. Replacement of cane sugar in many of its commercial uses by beet sugar and corn sweeteners has been a contributing factor.

Trade in barium hydroxide

Imports have risen from less than one per cent of domestic consumption since 1971 to the point that U.S. production has nearly ceased. Imports currently represent over 80 per cent of total domestic barium hydroxide consumption. West Germany, Italy and China are significant exporters to the United States and Canada. There is less than $50,000 worth of hydroxide moving from the U.S. into Canada.

Table 5.19
U.S. Barium Hydroxide Imports

	1988 (kt)
West Germany	2.6
Italy	1.0
China	0.3
Japan	0.3
All other	0.1
Total	**4.3**
Total value ($Cdn. million)	**5.0**
Canadian imports	**0.3 kt, 0.4**
Total value ($Cdn. million)	**0.4**

Producers

There remain only two North American chemical companies which occasionally produce barium hydroxide: Barium Chemicals, Inc. in Steubenville, Ohio and the J.T. Baker Chemical Co., in Phillipsburg, New Jersey.

Barium Sulphate (Synthetic)

Markets

The most significant market for barium sulphate (synthetic) is as a pigment and filler in trade paint applications. It is also used as a filler in rubber and plastic materials and as a paper coating and filler.

The market in North America is estimated at 10 kt per year, valued at close to $(Cdn.)8 million. Only two or three kt is produced in the United States and none in Canada.

Barium sulphate (synthetic) has suffered market erosion, due to competition from less expensive titanium dioxide pigments and fillers; that situation stabilized in the early 1980s. Precipitated product competes with finely-ground bleached barite, or unbleached barite.

Trade in synthetic barium sulphate

Imports currently represent 82 per cent of total domestic barium sulphate (synthetic) consumption in North America. West Germany and Italy are both significant exporters to the U.S.

Table 5.20
Available Canadian Imports Statistics for Barium Sulphate

	1986	1987	1988
Volume kt	0.8	0.9	n/a
Value ($Cdn. million)	$ 0.7	$ 0.7	$ 0.6

Producers

There are only three North American producers of barium sulphate (synthetic): Barium Chemicals, Inc. with its plant in Steubenville, Ohio, Pfizer Inc., with its plant in East St. Louis, Illinois and Whittaker, Clark and Daniels, Inc. with its plant in South Plainfield, New Jersey.

Other Barium Chemicals

Other barium minerals are derived from the intermediate barium sulphide including the nitrate, stearate, peroxide, and a variety of numerous other derivatives.

Imports currently represent 50 per cent of total domestic consumption. Italy, Spain and China are all significant exporters to the U.S.

There remain only three domestic specialty barium compound producers: Barium Chemicals, Inc., of Steubenville, Ohio, Chemical Products Corp., of Cartersville, Georgia and J.T. Baker in Phillipsburg, New Jersey. Two other North American producers make products for internal use—General Electric in Cleveland, Ohio and GTE in Tonawanda, Pennsylvania.

Table 5.21
U.S. Barium Nitrate Imports

	1988 (kt)
China	1.1
Italy	0.1
France	0.1
All other	0.1
Total	**1.4**
Total value ($(Cdn.) million)	**1.2**

Process technology

Manufacturing process

Barium chemicals are derived from a high-quality barite ore (barium sulphate) which is mixed with a carbon source in an energy-intensive process to reduce the sulphate to the sulphide. The sulphide is the starting material for most of the barium chemicals.

The process can be environmentally messy without proper controls for kiln-produced gases and byproducts. It is believed Chinese production involves little in the way of environmental controls, which can increase the cost of processing as well as the capital required for the plant.

World-scale plant capacity is in the range of 30-40 kt of barium sulphide, although the Chemical Production Corp. facility is believed to be of the order of 20-30 kt.

Total investment cost for a new facility would be in the range of $(Cdn.)20-50 million. A more attractive alternative would be to purchase a mothballed rotary furnace, which could decrease the investment significantly.

The major capital cost of the plant would be the rotary kiln, 20 per cent of the cost, so minimizing the cost of the equipment would enhance the return on investment for this opportunity.

Raw material requirement

For most applications the final barium chemical products requires low iron and silica content, so the ore should have a minimum amount of these impurities. In the operation, these materials form insoluble compounds, reducing the yield of desired product and generally limiting efficiency.

Barite prices are in the range of $170 - 300 per tonne, but mining the ore should not cost much more than $50 per tonne. Other raw materials including coal, soda ash and hydrogen chloride are readily available in Ontario and all of these products are well priced below $200 per tonne, so there seems to be enough in raw material margins to cover other costs.

Production of precursor - black ash

Barite is made into barium chemicals by first producing the intermediate barium sulphide. The molecular bonds between the barium and the sulphate group in the raw material are strong, so high temperatures and a carbonaceous agent are required to reduce the sulphate to the sulphide. The sulphide referred to as black ash, is impure and soluble in water. The primary reaction is as follows:

$$BaSO_4 + 4C \longrightarrow BaS + 4CO$$

Production can be carried out in a rotary kiln or a fluidized bed reactor, although in North America the former manner is used. The operating temperature of the process is at 1000 - 1250°C. Rotary kilns are typically two metres in diameter and 20 metres long. Residence time in the kilns is of the order of 2.5 hours. The capacity of the units is typically 30-40 kt of barium sulphide per year.

Powder black ash produced in the kiln is fed to a wet ball or rod mill, and subsequently to a series of countercurrent water leaching tanks, eventually yielding a 20-30 per cent barium sulphide solution. The leaching sequence is often a six-tank Dorr system.

Barium carbonate production

Barium sulphide solution may be reacted with various acids to produce the different salts, such as barium nitrate (reacted with nitric acid). Alternatively, the barium sulphide can be reacted with soda ash or carbon dioxide to produce barium carbonate. The following reactions describe the production of the carbonate.

$$BaS + Na_2CO_3 \longrightarrow BaCO_3 + Na_2S$$

The carbonate forms a precipitate and is filtered, washed, dried, ground and sold in solid form. The sodium sulphide still in solution can be sold for its sodium and sulphide value in kraft pulp mills. Approximately 0.3 kg of sodium sulphide are produced for every kg of barium carbonate.

A second route to the carbonate involves the reaction of the barium sulphide with carbon dioxide, which is bubbled

through the solution. The carbonate is precipitated out of solution and hydrogen sulphide gas is evolved. CPC reportedly uses this method of production for the carbonate.

$BaS + CO_2 + H_2O \longrightarrow BaCO_3 + H_2S$

The carbon dioxide can be supplied in pure form or can be the output of the combustion kiln.

By-product hydrosulphide gas can be converted into sodium sulphide, sodium hydrosulphide or other sulphur-containing chemicals. In the past in some installations, the hydrosulphide has been mixed with natural gas and incinerated to eliminate the unpleasant odor of the gas. The resultant sulphur dioxide is vented to the atmosphere.

Which method is chosen to produce the carbonate is determined by the characteristics of the desired material and the ability to dispose of the sulphur by-products. Barium carbonate produced via the soda ash process has a lower level of residual sulphides, but does not flow as well as the product produced via carbon dioxide. Carbonate via the carbon dioxide route has a higher level of sulphides in the final product. Capital equipment for the soda ash process is more expensive.

Barium chloride production

Barium chloride is produced from barium sulphide and hydrochloric acid. The solution is evaporated and the barium chloride is crystallized. Product is sold as the dihydrate (15 per cent moisture) or heated and sold in the anhydrous form.

The barium sulphide and the hydrochloric acid are reacted in a rubber-lined vessel, where the insoluble sulphides are filtered. Soluble sulphur compounds are further oxidized and precipitated out as barium sulphate, before evaporation is conducted.

Barium Hydroxide

Barium hydroxide can be made by dissolving barium oxide in hot water, and crystallizing out the hydroxide at low temperature. The Sherwin-Williams plant, which was closed in the early 1980s, made the hydroxide using barium sulphide as the raw material.

Precipitated barium sulphate

For some applications that require a higher purity of barium sulphate than that afforded by the ore, precipitated barium sulphate is used.

For the use of barium sulphate as a pigment, barium sulphide is reacted with sodium sulphate in solution to form barium sulphate and sodium sulphide.

$BaS + Na_2SO_4 \longrightarrow BaSO_4 + Na_2S$

The barium sulphate produced for this purpose is referred to as blanc fixe.

Lithopone is a white pigment containing barium sulphate and zinc sulphide. Lithopone is precipitated out of solution, dried and calcined to provide desired particle size.

$BaS + ZnSO_4 \longrightarrow BaSO_4 + ZnS$

Barium titanate

Barium titanate is generally produced in two ways. To obtain a high-purity material, ie. 99.9 per cent, barium chloride is reacted with titanium tetrachloride in oxalic acid to form the barium titanate. Most of the production of the titanate is produced in this manner. The purity of the barium chloride need not be high. Particle size and shape are not important features of the barium chloride since the chemical is dissolved for reaction.

Lower quality barium titanate powders are produced using barium carbonate powder and titanium dioxide. The mix of powders are calcined to form the titanate.

Particle size, particle shape and purity of the barium carbonate powders used are important in the calcination procedure, since they can affect the properties of the titanates produced. Barium carbonate for this application is generally purchased from Germany. Heavy metal contaminants should be minimized in the carbonate, and for this reason U.S.-produced material, which contains high levels of metals (i.e. stron[illegible]m), is not used by the major producers of titanates in the United States.

Discussion of potential

Growth in barium chemicals

Growth for all barium chemicals in the region of interest is not expected to be significant to the point where supply shortages exist. Offshore materials are in ample supply, so growth will not contribute to market tightness for the near term, unless offshore producers shut down.

Table 5.22
Canada and Northeastern U.S. Market Outlook for Barium Chemicals

	Canada	Northeast U.S. (1995, kt)	Total
Barium carbonate	5.0	12.0	17.0
Barium chloride	2.0	4.5	6.5
Barium hydroxide	0.4	3.0	3.4
Barium sulphate	1.2	1.2	2.4
Miscellaneous	-	0.3	0.3
Total	**8.6**	**21.0**	**29.6**

The major barium carbonate markets—bricks, glass, frits and porcelain—will grow at near GNP rates. The bulk of the barium carbonate market will cycle with housing starts. On the negative side, there could be some erosion of the clay brick market by cement bricks which currently do not use barium carbonate. On the positive side, the penetration of clay bricks in the northeast U.S. could increase from currently low levels. Additional clay brick capacity is being installed in Canada, possibly leading to exports to the United States.

Glass applications will grow at GNP rates, with increased production of computer monitors contributing positively, but a mature and possibly declining TV picture tube market will curtail gains.

Barium chloride for dyes will grow at GNP rates, but the barium titanate business will be static due to miniaturization and increases in efficiencies in material usage. Usage at Canadian uranium producers will not grow significantly. The world uranium market is in oversupply.

Barium hydroxide for greases and stabilizers is mature, although stabilizers should grow better than grease applications, in line with increased PVC production and usage in Canada and the northern United States.

The regional market would seem to offer some potential in supporting a plant to make barium sulphide, barium carbonate and other barium derivatives.

Business and technical considerations

The establishment of a facility to process barium chemicals is highly related to capital cost of such a facility and the need to develop a cost structure that will allow for regional competition. The investment can be major, so opportunistic acquisitions of standard equipment such as a kiln, tanks, etc. would help the economics. On an operational basis, the chemical firm should have flexibility to adjust its barium sulphide derivatives production to opportunities in the market.

The carbonate business and the chloride business may be the ones to provide base volume. If careful consideration is given to product purification, many of the areas of application such as electronics or pharmaceutical uses could open up, displacing material imported from Europe. High-quality products might have export opportunities as well.

The production plant would require careful engineering. The toxic nature of barium and some of its compounds means that environmental and process design factors will weigh heavily in obtaining plant approval and in operating a facility. Air pollution control and product handling systems could add substantially to the cost of a plant, since operational standards have increased in these areas since the last plant was built in North America. Additionally, the operators of any barium plant would have to be highly knowledgeable in chemical operations and workplace safety.

In summary, the barium chemicals markets seem to have flattened out from their slide of the 1970s and early 1980s and, with the reduction in the number of producers, there could be a future opportunity for a new plant. Such a plant would be likely to be in a position to take over regional markets and look to expand its business scope in the future.

Precipitated Calcium Carbonate

Basis for opportunity

Precipitated calcium carbonate (PCC) is primarily used as a pigment and filler. Major market areas include paper manufacturing, paints and as a plastics additive. Growth and changes in the paper industry are expected to have the greatest effect on calcium carbonate and it is this growth in Canada and the northern U.S. that provides opportunity. We have only investigated the PCC opportunity, based on production involving a chemical process. Mechanically-processed ground calcium carbonate is also a growth market and could present an opportunity for "non-chemical" companies.

Technical changes in making paper are resulting in the displacement of clay fillers with calcium carbonate in paper. The trend to produce better-quality papers using alkaline conditions allows the carbonate to be used rather than clay, which is suited to acid-based paper production. It is this trend to alkaline paper making that provides the basic thrust of the chemical's potential.

The factors for an opportunity in calcium carbonate are as follows:

- potentially two to three plants needed in next five years;
- product sold "over-fence" to paper mills;
- suitable quality limestone needed as raw material.

A second factor is production technology and supply considerations. The precipitated product is made in small plants that are located on-site to major paper mill customers. This means that shipping and handling costs are reduced on the final product from these units, thus providing further competitive advantage versus other fillers. Suitable clay deposits are located mostly in the state of Georgia, whereas calcium carbonate deposits are more likely to be available closer to markets. Specifically for Ontario we are likely to see, in the coming three to five years, both an increase in the ground calcium carbonate market in the paper mills as well as the potential for two or three on-site precipitation plants to be established in the province.

Markets and producers

Markets for calcium carbonate

Two forms of calcium carbonate compete in several markets. Ultra-fine ground (UFG) material has many established applications, while the precipitated material, which is chemically produced rather than physically processed, is gaining position in many other applications for technical reasons.

In the U.S. the growth in calcium carbonate demand as a filler for paper is for the precipitated form. The Canadian market is slightly different, with new paper machines being installed in Eastern Canada for making coated product. These units will most likely use UFG material, unless precipitated plants are installed close by. Advantages of PCC over wet-ground calcium carbonate for filler use include density, bulk and narrow particle size distribution. The wet-ground form is preferred for coating applications.

Table 5.23
Demand for Calcium Carbonates in North America

	1988 (kt)
Precipitated	275
Ultra-fine ground	530
Total	**805**

Merchant list market prices are $(U.S.)212/ton bulk quantities, FOB for PCC and $(U.S.)150/ton bulk, FOB, for wet-ground. Prices for on-site produced PCC are not available from the two producers, since such information is considered proprietary between the paper mill and the PCC producer. Currently, the supply of wet-ground calcium carbonate is in excess and purchases are being made below list prices.

Precipitated calcium carbonate markets

The total North American market for precipitated calcium carbonate in 1988 is estimated to be 275 kt, or 10 per cent higher than the 1987 demand. Depending on-end use, prices varied from $(U.S.)200-350/tonne. Total market value was in excess of $(U.S.)75 million.

The most significant market for calcium carbonate is its use as a filler and coating ingredient in paper production. The entire paper industry is experiencing rapid growth, coupled with a rate of technological change unprecedented in its history. These two factors have led to a complicated interplay of material competition and, in some cases, product scarcities. Major issues affecting paper chemical demand include: alkaline papermaking, 100 per cent water recycling, need for higher-quality paper coatings and changes in beater recipes. These factors present growth opportunities for calcium carbonate, particularly for precipitated grades.

Table 5.24
North American Outlook for Precipitated Calcium Carbonate

	1988	1995	Average Annual Growth Rate (%)
	(kt)		
Paper Filler and Coatings	180	400	12
Paint and Plastics	26	30	2
Other	64	70	2
Total	**270**	**500**	**9**

Pulp and paper applications are generally the only high-growth area for precipitated calcium carbonate. The more even particle size can give PCC material preference over fine-ground carbonate.

On fine papers of the copy or xerography grades savings of 20 per cent to 33 per cent are possible by switching over to alkaline papermaking and increasing the percentage of filler in the paper. This involves reducing the pulp content to effect the saving.

Xerox Corp., one of the major buyers of light printing and copy paper, is proposing to switch its paper-buying over to alkaline paper, provided dusting and flatness can be controlled. While the copier manufacturer prefers clay, it rates precipitated calcium carbonate ahead of UFG material in its paper specifications. With pulp selling at $(Cdn.)900 per ton and carbonate at $(Cdn.)250/ton approximately, a 10 per cent increase in filler through using calcium carbonate drops the raw material cost on a tonne of paper by seven to eight per cent and filler levels can be raised to reduce paper costs by 15 per cent or more.

Table 5.25
Outlook For Calcium Carbonate Consumption in Paper

	1988	1995	Average Annual Growth Rate (%)
	(kt)		
UFG	450	770	8
Precipitated	180	400	12
Total	**630**	**1,170**	**9**

UFG calcium carbonate markets

The size of the total U.S. market for UFG calcium carbonate in 1988 was 530 kt. At an average spot price of $(U.S.)190/tonne, this represented a total market value in excess of $(U.S.)100 million.

The production of Calcium carbonate (UFG) from limestone ore is accomplished by a combination of milling and grinding. Desired properties are consistent particle size (less than one micron), consistent shape and low color content.

The most significant market for UFG calcium carbonate is its use as a filler and coating ingredient in paper production.

Calcium carbonate is also used as pigment and filler in trade paint applications and as a filler in rubber and plastic products. In these applications, calcium carbonate's inertness and low cost provide it with a market position. The following table presents a forecast of expected UFG calcium carbonate consumption through 1995.

Table 5.26
U.S. Outlook For UFG Calcium Carbonate Consumption

Application	1981	1988	1995	Average Annual Growth Rate (%) (1988-1995)
		(kt)		
Paper Filler and Coatings	353	450	770	8
Trade Paint	50	53	60	2
Rubber and Plastics	22	27	35	4
Total	**425**	**530**	**865**	**7**

In 1981, U.S. calcium carbonate consumption totaled 425 kt. This total grew slowly (3.2 per cent annually) to 530 kt by 1988. The pace of growth should be faster in the following seven years. Demand by 1995 is likely to approach 865 kt. Competition against clay for alkaline papers, a general increase in filler levels in pulp recipes and increased paper use are all expected to contribute to calcium carbonate's growth outlook into the early 1990s.

Carbonate market in the region

The market in the northeastern United States consists of six paper mills with on-site PCC units serving their needs. There are 10 PCC units, all but one of which are on-site producers tied to specific paper mills. This year the first Canadian plant will start operating in northwestern Ontario.

Great Lakes Paper at Dryden, Ontario—a Canadian Forest Products subsidiary—is installing a new paper machine and going to PCC-filled alkaline paper making this year (April 1989) on their existing machine as well. They have had some alkaline paper production for many years. Now Pfizer is building a

PCC plant and the mill may use the "Compozil" colloidal silica/cationic starch retention aid system along with AKD (alkyl ketene dimer) reactive size. This project is being watched by others to evaluate the process.

There are several other fine paper mills which are in the process of evaluating alkaline paper production and represent the most likely future consumers of precipitated calcium carbonate.

Table 5.27
Estimated Regional Use of Precipitated Calcium Carbonate

	1988 (kt)
Northeastern U.S.	105
Ontario/Quebec	2
Total	**107**

In the fine paper area in North America the major players tend to be International Paper, Consolidated Paper, Weyerhaeuser and James River. There are more than 50 mills in the U.S. running some alkaline machines, and this trend is spreading. The first major mill to move to this route was International Paper at Ticonderoga, NY, which started much of the trend. Pfizer has a PCC unit on-site for International Paper there.

Table 5.28
Estimated Regional Use of UFG Calcuim Carbonate

	1988 (kt)
Northeastern U.S.	220
Ontario/Quebec	15
Total	**235**

Calcium carbonate is used in several ways in paper-making. In fine papers it is used as a filler and also as a paper-coating material. For filler use PCC is most often used, but UFG or even a mix of the two can be employed. For fine paper coating UFG material tends to dominate. The second major application area is in kraft paper and paperboards as a pigment. This application is dominated by UFG material.

Use in kraft paperboard and coated sheet is expanding as well as in fine paper. The penetration of calcium carbonate is greater against other fillers however, and the overall growth, in paperboards in particular, is much lower than uncoated sheet and offset paper or even coated papers.

Producers

There are currently two merchant producers of precipitated calcium carbonate in the U.S. and one in Canada. Canada will have two producers when Pfizer builds a dedicated on-site unit with a capacity of 30 kt/yr at the Dryden, Ontario mill of Canadian Pacific Forest Products.

Pfizer has several plants in the northeastern U.S. region making PCC on-site. They have a major plant at Adams, Massachusetts, Glen Falls, New York, and Ticondoroga, New York among their ten or so plants across the U.S. Continental Lime is the newer entrant to the on-site plant business and their plants are going up at Weyerhaeuser Canada's mill in Prince Albert.

The merchant supply of PCC is tied almost exclusively to over-the-fence delivery to paper mills under long-term contracts. The major advantage for the mills is that the material is delivered in slurry form right to the head-box of the paper machine. The service aspect helps determine the location of the PCC plants alongside the major fine paper mills in the region that have switched to alkaline papermaking.

Table 5.29
Current North American Producers of Precipitated Calcium Carbonate

Company	Location	Total Capacity + (kt)
U.S.		
Mississippi Lime Co.	St. Genevieve, Missouri	160
Pfizer	Various	220*
Canada		
Continental Lime	Prince Albert, Saskatchewan	42*
Pfizer	Dryden, Ontario	30
Total		**452**

+ Includes all plant sites

* Capacity includes pulp mill on-site production units

In addition to the merchant plants, one or two of the fine paper mills have their own PCC units. Finch Pryn of Glens Falls, New York, for example, has its own plant, developed internally.

The production of UFG calcium carbonate is done by a larger and more regionally varied group of companies in the field. There are two firms in Canada—one in Ontario and one in Quebec—serving the pulp and paper, paint and carpet backing filler markets in the region.

Table 5.30
North American
Calcium Carbonate (UFG) Producers

Company	Location	Capacity (kt/yr)
U.S.		
OMYA (Pleuss-Stauffer AG)	Vermont	300
English China Clay Americas	Maryland, Georgia Alabama, Vermont	100
Mississippi Lime Co.	Missouri	70
Columbia River Carbonates	Washington	50
Continental Lime	Washington	40
Other	—	30
Canada		
Ressources Carbec	Quebec	45
Steep Rock Calcite (Pleuss-Stauffer AG)	Ontario	45
Total		**680**

Process technology

Precipitated calcium carbonate is manufactured by precipitating carbonated calcium hydroxide produced by hydrolyzing thermally-reduced limestone. Steps in the process involve putting high-purity lime into solution (possibly using hydrochloric acid) and then bubbling carbon dioxide through the solution to precipitate out the product. Although it is considerably more expensive to produce than milled and ground natural calcium carbonate, it has very even particle size and a lower level of colored impurities than UFG calcium carbonate.

Two companies currently build, operate and own on-site facilities for the production of PCC slurry used as paper filler in North America. Pfizer Inc. of New York City dominates the market and has about eleven such units in operation. The company has several other units under construction including one at Canadian Pacific Forest Products in Dryden, Ontario. Continental Lime, Inc. of Tacoma, Washington and Mississauga, Ontario is a more recent, smaller participant in this market and recently furnished the on-site PCC unit for Weyerhaeuser Canada's new 220 kt/year uncoated free-sheet paper mill in Prince Albert, Saskatchewan. (Continental Lime Inc. is a wholly owned subsidiary of Continental Lime, Ltd.—the former Steel Brothers Canada, Ltd.) A third company, Mississippi Lime Co. of Genevieve, Missouri, produces and merchant-markets PCC for paper filler use in both powder and slurry form. This company is not active in on-site production.

Table 5.31
Typical Plant Specifications

Capacity	20-45 kt/yr
Capital costs	$7-10 million
Man-power	8-10 people
Raw material	15-25 kt/yr of limestone

Technology used to produce PCC on-site is considered confidential by producers. A reported breakthrough in technology came in 1982 when Pfizer developed a formulation for stabilizing the PCC slurry, thus eliminating the need to dehydrate and re-hydrate before and after shipping. The necessary starting materials are lime, water, and carbon dioxide. The cost advantage of having a locally available, high-quality grade of lime is passed on to the paper mill customer in the ultimate price of the on-site generated PCC. Carbon dioxide is usually readily available from the paper mill exhaust stacks. Water and electricity are other material cost components; their prices vary depending on local sources and availability.

The on-site PCC producers normally lease property for the unit at the paper mill, or adjacent to it, and pipe the PCC slurry directly into the mill. All units are operated by PCC producer personnel to ensure product quality and maintain confidentiality of the process. An economically feasible size for an on-site PCC generation unit appears to be 30,000 tonnes/year. A rough capital cost estimate to construct this size unit is about $(U.S.) 7 million, according to one producer. Normal economies of scale would hold true. Pfizer's Longview, Washington PCC plant for Weyerhaeuser Paper Company, now due for startup, will employ ten people.

Both Pfizer and Continental Lime have indicated they are unwilling to sell or license their precipitated calcium carbonate technology. Pfizer knows of no advantage to them for entering a joint venture arrangement to build an on-site PCC plant in Ontario. The company does not believe there is need for another PCC plant in this region at the present time; in the future, possibly.

Continental Lime, on the other hand, indicates that there is the opportunity for another on-site unit in Ontario, due to the number of fine paper suppliers in the region and the increasing consideration of use of calcium carbonate instead of kaolin by paper manufacturers. The company expressed interest in and a willingness to discuss an on-site PCC plant with interested parties.

Discussion of potential

Raw material availability and grade

Production of PCC can be initiated from lime-calcium oxide, which itself is derived from roasting limestone (calcium carbonate) in a kiln. Producers of PCC are likely to purchase lime from merchant suppliers, rather than invest in kilns to start from the limestone.

Raw materials for making PCC in on-site plants are lime and water. The other major production ingredient is carbon

dioxide, which is usually available at the pulp mill. The volume of lime required by a plant basically equals 60 per cent of the capacity of the plant's production. The carbon dioxide can come from stack gases or merchant gas supply.

Should two or three more on-site plants be located in the province of Ontario in the coming five to seven years, the additional demand for lime would probably run in the 30 to 50 kt range.

The important component for making precipitated calcium carbonate is a suitable quality of lime for the on-site plants. Lime quality is important, with magnesium and iron contamination also as major considerations. In part, the art of PCC manufacture is in the lime selection. On-site plant producers tend to guard the exact lime quality specifications.

Supply of lime to the Ontario plant that is being started up this year is likely to come from the United States. Quality of the local lime for PCC manufacturing is apparently under consideration.

Lime producers with roasting kilns in Ontario and Quebec include; Algoma Steel at Sault Ste. Marie, Ontario; Allied at Amherstburg, Ontario; BeachviLime in Beachville, Ontario; Reiss Lime Co. of Canada at Spragge, Ontario; Steetley Industries Ltd. of Dundas, Ontario; Domlim Inc. at Lime Rodge, Quebec.

Although many of the pulp and paper mills themselves currently purchase limestone for the production of lime as a recausticization chemical, there has been no evident interest in the production of PCC. Reasons for this reluctance to initiate PCC production at this early stage in the chemical's development as a paper additive may include: lack of appropriate technology to produce quality material; lack of suitable grades of limestone; and lack of capacity at the kiln—some companies are purchasing lime from merchant suppliers. As the production and application technology matures in the future 15 to 20 years, more mills may go to internal production.

Growth outlook and timing of opportunity

By 1995, alkaline papermaking is expected to be adopted by at least half of the paper mills in North America currently producing fine papers. This will translate into greater use of calcium carbonate, which although not suitable in acid paper production, is well suited to alkaline systems.

Part of the drive behind the move to alkaline papermaking and the use of calcium carbonate lies in the ability to use more filler rather than pulp, particularly in copy paper, uncoated sheet, light bond and products for the printing industry that use uncoated sheet product. In these products, alkaline production technology allows filler levels to increase from the 5 to 10 per cent range to as high as 30 per cent. As pulp prices are more than twice that of calcium carbonate, the paper mills can effect major product cost savings.

Opportunities for PCC relate to on-site facilities, so we have only investigated possible Ontario production. More specifically, there are two areas in Ontario where precipitated calcium carbonate plants may be installed in the coming three to seven years.

In terms of the Ontario paper industry, there could be at least two or three new PCC plants built in the next 5 to 10 years. We have assumed that two plants will be built and that the total market will be 55 kt by 1995.

In southern Ontario we include four paper producers. A survey of the mills found that the Niagara area has one mill conducting trials this year and another seriously thinking of using an alkaline system with calcium carbonate.

Table 5.32
Southern Ontario Region Fine Paper Mill

		Capacity (kt)
Domtar	St. Catharines, Ontario	70
Fraser	Thorold, Ontario	96
Abitibi-Price	Georgetown, Ontario	15
Domtar	Toronto, Ontario	13

Our assumption is that at least one of the larger mills (probably Fraser) will switch to alkaline paper production by 1995 and that precipitated calcium carbonate will be required. This conservative assumption would result in annual demand for an estimated 15 kt of PCC. Additional demand could be present if Domtar or the smaller mills convert. An on-site facility or a regional supplier could service this market.

Another cluster of fine paper mills, at least one of which we are assuming will convert to alkaline papermaking by 1995, is in the Ottawa-Hull-Cornwall region of Ontario. Again, a regional PCC producer could serve any or all of the mills in the region. Demand for the region is conservatively estimated at 15 kt per year.

Table 5.33
Fine Paper Mills in Eastern Ontario/Quebec border

		Capacity (kt)
E.B. Eddy	Ottawa, Ontario	62
E.B. Eddy	Hull, Quebec	91
Domtar	Cornwall, Ontario	210

For northwestern Ontario mills thinking of switching to alkaline fine papers and of using calcium carbonate, freight costs make an on-site plant most attractive. Abitibi-Price at Thunder Bay uses calcium carbonate and could use PCC supplied by Pfizer from its 30 kt/year plant at Dryden. Our base case assumption is that another PCC plant would not be required in the region by 1995, despite the possibility that

Boise-Cascade may move some of its production at Fort Frances and International Falls to alkaline systems.

Table 5.34
Fine Paper Mills in Eastern Canada

		Capacity (kt/year)
Abitibi Paper	Thunder Bay, Ontario	140
Abitibi Paper	Georgetown, Ontario	15
Domtar Inc.	Beauharnois, Quebec	28
Domtar Inc.	Cornwall, Ontario	210
Domtar Inc.	Toronto, Ontario	13
Domtar Inc.	St. Catharines, Ontario	70
Domtar Inc.	Windsor, Quebec	96+250
E.B. Eddy Paper	Espanola, Ontario	38
E.B. Eddy Paper	Hull, Quebec	91
E.B. Eddy Paper	Ottawa, Ontario	62
Fraser Inc.	Thorold, Ontario	96
Great Lakes Forests	Dryden, Ontario	123
Rolland Inc.	Mont-Rolland, Quebec	28
Rolland Inc.	St-Jerome, Quebec	140

In the uncoated sheet market, Domtar has a strong position. With its new mill at Windsor, Quebec (which, although with an acid system, could switch, to alkaline in the future) plus the Cornwall and St. Catharines mills, its decision on alkaline papermaking will have a major impact on the carbonate market. Rolland will be concentrating more on specialty papers in the future, i.e. decor papers, so the company may be less of a factor on demand for PCC in the future.

Lime (calcium oxide) sales

Apart from on-site Ontario PCC opportunities, the market is likely to boom in terms of the use in fine paper. Therefore for current lime suppliers, roasting the limestone could sell their product to regional and on-site PCC producers if the appropriate quality of lime is available from their operation.

Ontario, Quebec, New York, Ohio, Maine, Vermont and Pennsylvania comprise some 50-60 per cent of the continent's capacity for fine papers. About 20-25 per cent of production is on the alkaline papermaking process and by 1995 it appears that upwards of 50 per cent of this paper sector will be producing alkaline product. That could boost the consumption of calcium carbonate in the region to an estimated 250-350 kt in fine paper. Precipitated calcium carbonate is expected to account for the greater increase, as on-site PCC plants are installed at the larger mills making the switch.

Table 5.35
Estimated Regional Growth of Precipitated Calcium Carbonate

	1988	1995
	(kt)	
Northeastern U.S.	105	240
Ontario/Quebec	2	55
Total	**107**	**295**

Colloidal Silica

Basis for opportunity

Colloidal silica is a mature chemical that has potential to undergo a resurgence in market interest. The opportunity expected to develop in the context of a producer in Ontario or close to Ontario will lie in the application of colloidal silica in papermaking, where its use is expanding.

As with calcium carbonate, the move to alkaline papermaking is offering many new opportunities for chemicals and much of the growth in colloidal silica is tied to this application.

The factors for opportunity in colloidal silica are as follows:

- paper usage could double in next 5 years in regional market;
- a high-tech application of silica technology;
- a high-service product in many applications.

Canada has a growing and potential requirement for colloidal silica, or silica sol, in two different pulp and paper applications. Colloidal silica is used as an antislip agent for paperboard, the largest current Canadian market for the product. With the trend towards increased use of neutral or alkaline papermaking techniques, demand for a colloidal silica as a component in fiber retention systems is expected to increase. The necessary characteristics of the colloidal silica in these two applications differ; antislip coatings require a large particle diameter (approximately 20 µm), while retention aid use requires a small particle size (about 5 µm).

The negative side of this opportunity involves the timing of the market demand and the supply position to the industry. At this point, there is one major patent, held by Du Pont, on the use of colloidal silica as a retention aid/binder in neutral papermaking to achieve high filler levels. How the licensing of the patent will affect the supply of colloidal silica to the industry is unclear at this time. Furthermore, the development of any colloidal silica opportunity in the regional market is estimated to be at least five years away.

Markets and producers

Markets for colloidal silica

Colloidal silica, or silica sol, is a suspension of fine silica particles in an aqueous medium and is derived from sodium silicate. Its major applications are as a binder in investment castings, in paper processing and coating, in silicon wafer polishing and as a binder in refractories.

The U.S. market for colloidal silica reached approximately 12.7 kt in 1988 and was valued at approximately $40 million. Overall demand for colloidal silica in all applications is expected to grow at an average annual rate of 3.5-4 per cent per year for the next five years. Prices vary with the grade of silica, with electronic-grade material running $4-4.25 per kg and other grades in the $2.50-3.00 per kg range.

Expected growth rates in the various market sectors are difficult to determine precisely. Investment casting is dependent on the aerospace industry, which in turn is dependent on commitments for defence spending. Growth should be slow over the next several years, but could pick up in the early 1990s. Monsanto's recent exit from the electronics business may also affect future demand for colloidal silica. Whether increased foreign ownership of U.S. silicon wafer production will lead to a shift in silicon wafer offshore is uncertain, with corresponding uncertainty in the U.S. demand forecast.

Table 5.36
U.S. Consumption of Colloidal Silica (100% SiO_2 basis)

	1988 (kt)	1995	Annual Growth Rate (%)
Investment casting	4.6	6.1	4
Pulp and paper	3.2	6.9	12
Wafer polishing	2.3	3.4	6
Refractory binders	1.4	1.5	1
Miscellaneous *	1.3	1.4	1
Total	**12.8**	**19.3**	**6**

* Includes catalysts, antiblocking agents, etc.

The pulp and paper market is really two sectors. In antislip coatings, growth will probably track linerboard production at 2-2.5 per cent annually. Silica-containing fiber retention systems are still in the introductory phases, and the rapidity with which they will be accepted is uncertain. Demand for these filtration/retention aids would be expected to track alkaline papermaking. The use of neutral or alkaline size is becoming increasingly popular in some sectors of the papermaking industry, but penetration of these market sectors is not yet complete. Growth in silica demand may be quite rapid if mills accept these systems, but the growth will be from the very low currently-installed base.

Annual consumption of colloidal silica in Canada is 1,000-1,500 tonnes. Usage varies with the level of manufacturing activity in the paperboard and steelmaking industries, which together account for 80 per cent of consumption. Consumption in end-use markets is estimated to be: (a) paperboard, 55 per cent; (b) steel and foundry, 25 per cent; (c) other, 20 per cent.

Colloidal silica in the paper industry

The use of colloidal silica in the paper industry started out with the anti-slip coatings on box and paperboards that was pioneered by Du Pont. Recently, the use of the chemical has expanded into the fine paper area as a product that helps to retain fillers in alkaline papermaking as well as provide additional properties, particularly in printing and copy papers.

In paperboard (boxboard and corrugated board) manufacturing, colloidal silica is applied to board surfaces as an anti-

slip or frictionizing agent. It is used for board destined for box or carton end uses where stacking and palletizing is customary. One large use is for beer cartons. Such antislip treatment is often applied to boxboard having high-gloss coatings, desirable for quality printing. The treatment is also sometimes applied to paper bags.

Colloidal silica is applied to board at either the board mill or at the converting (box-making) plant, the former accounting for the largest volume. For efficiency in handling, the converters prefer to use pretreated board stock. A spray form of colloidal silica is also used in warehouses as a package antislip treatment. Slip-resistant palletized packages can save costs by eliminating the need for stretch-wrapping.

The dominant use in fine papers at this time is the "Compozil" system being marketed by Procomp of Augusta, Georgia. An outgrowth of European papermaking technology, the process was developed by Enka-Nobel of Sweden and Du Pont. Procomp is a 50/50 partnership between the two companies and its patents cover the fine paper applications.

The Procomp patents chiefly describe a process for using two common chemicals in combination for paper production to achieve high calcium carbonate filler levels. The two are cationic starch (e.g. potato starch) and colloidal anionic silica, the latter being the more important of the two components and explaining some of Du Pont's interest. The patent covers the use of the two chemicals over an application range to achieve paper properties over a particular range.

The experience of the paper industry to date seems to be that the economics of colloidal silica and starch apply only at the filler levels covered by the patent. A major issue in the paper industry will be how the components are supplied and how the Enka-Du Pont patent is licensed in the coming years, as the industry evaluates and utilizes this type of high-filler level technology.

"Compozil" works very well within a narrow neutral pH range, but performance reportedly drops off dramatically in acid or alkali pH levels. As a result, the system requires the employment of very sophisticated process monitoring equipment to constantly measure and adjust whitewater parameters to maintain pH at seven and to meter the appropriate chemical dosages.

The ability to move the paper filler levels from the 5-10 per cent range to 20 per cent and above is the major attraction of "Compozil". With fillers costing 25-35 per cent of merchant pulp, the paper mill has the ability to achieve major savings on its product, particularly copy papers, offset paper and coated printing papers. As the paper industry switches to alkaline papermaking and the competitive pressure on costs hits the mills, it is expected that more and more mills will start to incorporate more fillers, and colloidal silica and cationic starches along with alkaline sizes will play a major role.

"Compozil" is more than a retention aid system and so cannot be classed with, or compared with, conventional retention aids. Colloidal silica, one component of "Compozil," is a very effective retention aid and performs this function in practice. But retention is secondary to the other objectives of Compozil. The chief benefit is the improvement of paper sheet strength, and hence paper quality.

It increases internal, surface, tensile and all the other strength criteria applied to paper, save only tear strength, which is primarily a function of fibre length. The strength gains are due to better retention, water drainage and paper formation. Improved strength in turn enables paper mills to increase both the filler and hardwood content of the pulp furnish, where this is economically attractive. Improved paper strength also permits greater latitude in coating practices, bringing benefits in coating quality, economy or both. However, the key contribution of "Compozil" to papermaking is improved sheet quality, especially with regard to printability. To that extent the system allows increased filler levels, which also help to improve brightness and opacity.

As the use of the patented process increases among alkaline papermakers, the market for colloidal silica will be likely to widen as technical improvements are made and the mills gain experience with silica, starch and fillers.

Competitors have been eyeing the field. Nalco marketed a system, Positech, that improved retention, but did not get into the concentrations or the filler loading levels of the Compozil patent.

Producers

Several of the U.S. producers are especially strong in specific market sectors such as paper. Du Pont pioneered antislip coatings for linerboard, and Nalco has developed the investment casting market. Both Nalco, through its Rodel subsidiary, and Monsanto have until now provided formulations and technical service for wafer polishing. Both Nalco and Du Pont (through the Pro-Comp joint venture) are marketing silica-cationic starch systems for improved retention in papermaking. Both wafer polishing and pulp retention systems provide significant value-added opportunity, and both require significant development and technical service. PQ Corporation serves a wider range of markets.

The U.S. producers of colloidal silica (1988) are as follows:

Company	Plant Location
E. I. Du Pont de Nemours & Co.	East Chicago, Indiana
Nalco Inc.	Chicago, Illinois
PQ Corporation	Ashland, Massachusetts South Gate, California
Ferro Corporation, (Transelco subsidiary)	Dresden, New York
Pro-Comp Inc. (joint venture of Du Pont and Eka Nobel)	Augusta, Georgia

None of the above producers is basic in silica, and only Du Pont and PQ Corporation produce their own sodium silicate. Du Pont and Nalco serve world markets from their U.S.

production, although exports are relatively minor.

Alchem Inc., in Burlington, Ontario is the sole Canadian manufacturer of colloidal silica. The product is also imported by Alchem from its U.S. affiliate, Nalco. E.I. Du Pont de Nemours in the U.S. is the other major source of imported colloidal silica, which is brought in by Du Pont Canada Inc. and sold through distributors. Alchem, Nalco and Du Pont have an estimated 99 per cent of the Canadian market.

Should the paper market grow substantially, it is likely that a specialized plant could be required to serve the regional market, much as the Pro-comp plant is serving the U.S. paper market today.

Process technology

Manufacturing process and technology

Colloidal silica is produced from a solution of sodium silicate. One method is to pass the solution through an ion exchange to partially remove the sodium ions, forming a silica suspension. A second method involves the removal of the sodium ions by electrodialysis. The sodium removal step then allows the silica to grow particles of the desired size for the sol. Once the particles are grown to the desired size, the sol is concentrated by evaporation or ultrafiltration. There are engineering differences among the different U.S. producers, but they are not believed to be substantial because the final products are found to be very similar.

Once the colloidal silica is formed, it can be surface-modified. Aluminate ions will provide aluminosilicate surfaces that are more gel-stable in the presence of salts, while hydrated metal cations can act as bridging compounds and turn the silica into a flocculating agent.

Colloidal silica is a derivative of sodium silicate and is sold as a dispersion in water with activity levels of 20, 30 or 50 per cent silica. Approximately 10 technical grades are offered in Canada, varying with activity, silica particle size and with the nature of the countervailing ion. Colloidal silica has a pH of 14. One shortcoming of the material is that it gels irreversibly if the solution temperature drops below 10° C.

Firms with colloidal silica technology are identified as follows:

PQ Corporation	Valley Forge, Pennsylvania
Du Pont	Wilmington, Delaware
Nalco	Chicago, Illinois
PPG Industries	Pittsburgh, Pennsylvania

Beyond the general production process described earlier, the details of colloidal silica production are considered proprietary. It is doubtful that any of the producers would wish to sell or license their technology. However, all may have an interest in Canadian production at some point in time.

Discussion of potential

Raw material availability

Given the size of regional demand for colloidal silicates, a producer would be likely to purchase sodium silicate and process it from there. The supply of silica in Ontario is suitable for making sodium silicate. The volume of sodium silicate required is likely to be not more than five to six kt a year, should a colloidal silicate operation start in the region.

The supply of sodium silicate to the Ontario and Quebec market is handled by National Silicates, the subsidiary of PQ Corp. of Valley Forge, Pennsylvania. The firm now has three plants across the country, making sodium silicates of various types for the pulp and paper industry as well as the other soluble silicate applications. National Silicates also makes potassium silicate in its eastern plants.

The sodium silicate plants in eastern Canada are:

National Silicates	Valleyfield, Quebec
National Silicates	Toronto, Ontario

The raw material for sodium silicate is silica sand. The sodium silicate process involves the manufacture of soluble glass in a furnace, which is then put into solution. Sand for making sodium silicate comes from the U.S., and the potential for an Ontario silica producer to supply the silicates business is strong. The local silicas are high in aluminum and iron for the use of National Silicates, and so the Canadian plants import their raw materials. The sand could possibly have its trace contaminants removed with acid leaching, but to date that type of processing has not been established in Ontario.

While the sodium silicates field is fairly mature, except for pulp and paper, and well supplied at this time in Canada, the potential for the supply of silica sand with the proper low levels of aluminum and iron would run in the 50,000 tonnes-per-year range. Any major move in the production of colloidal silica in the province is likely to increase that volume.

There is an opportunity to provide high-quality silica sand to the sodium silicate plants in both Ontario and Quebec. The present supply is from Illinois and Wisconsin, and local supply would be seriously considered. The annual volumes of sand going into the silicates business in Canada is around 50,000 tonnes per year.

The general problem with local sand is apparently the alumina and iron content, and washing the sand with acid to leach out the offending elements is a possible process to upgrade the sand.

The specification on sand for sodium silicate manufacture is as follows:

SiO_2 content	min 99.4%
Al_2O_3 content	max 0.20
Fe_2O_3 content	max 0.03
TiO_2 content	max 0.05
CaO/MgO content	max 0.05

Growth outlook and timing of opportunity

The established market for colloidal silica has been the use on boxboard that was pioneered by Du Pont several years ago.

Growth in paper application lies in the wet-end of paper machines as part of alkaline paper-filler systems where the material helps impart filler retention and strength properties to the paper.

Table 5.3
Growth in Paper Colloidal Silica in North America

	1988	1995
	(kt)	
Boxboard	2.4	2.4
Fine paper	0.8	4.5
Total	**3.2**	**6.9**

Source: Law, Sigurdson & Associates

The growth in colloidal silica in the regional market to Ontario will be tied to the use of the product in making paper. Application levels run at one to four kg per tonne of pulp and we estimate that the regional market will swing to alkaline papermaking in a major way between now and 1995.

Hydrofluoric Acid and Fluorspar

Basis for opportunity

The production of hydrofluoric acid could offer a potential industrial mineral opportunity for an Ontario fluorspar deposit owner. The mineral is the raw material for the manufacture of hydrofluoric acid, which is carried out in the province at Amherstburg, Ontario by Allied-Signal Can. da.

Fluorspar, the raw material for this production, is all imported into Canada, mainly from mines in Mexico. The volume of rock brought into the country has varied from year to year but has been in the range of 100 to 160 kt, with acid-grade material accounting for an estimated 75 per cent of that figure.

The development of technology for the flotation and refinement of fluorspar could provide an opportunity in the coming years. Demand for hydrofluoric acid could rise as the present types of chlorofluorocarbons (CFCs) are phased out and a new generation of CFCs are substituted. Some promising new types of hydrofluorocarbons tend to have a higher content of fluorine and less chlorine and will therefore require more hydrofluoric acid to produce.

Markets and producers

Fluorine chemicals

Hydrofluoric acid and its fluorine chemical derivatives are derived from fluorspar ore, a naturally-occurring calcium fluoride. While fluorspar's primary use is as a precursor for hydrofluoric acid and specialty organic and inorganic fluorides, fluorspar also finds significant use in the steel and aluminum industry, where it is used as a slag-fluxing material and for the production of synthetic cryolite. These applications are roughly 40 per cent as large as fluorspar use in hydrofluoric acid and specialty chemical production.

Table 5.38
North American Consumption of Hydrofluoric Acid

Market	1974	1981	1987	1995	Growth Rate '87-95 %/year
			(kt)		
Fluorocarbons					
Aerosols	62	4	5	7	4
Refrigeration and air conditioning	35	86	95	140	5
Blowing agent	10	35	40	60	6
Others	13	35	45	55	3
Aluminum manufacture					
Merchant	35	20	10	13	3
Captive	60	80	95	125	3
Gasoline alkylation	10	15	20	25	3
Stainless steel pickling	5	7.5	12	14	2
Uranium salt production	10	12.5	8	5	-6
Specialty metal manufacturing	5	8	12	18	5
Organic precursor	5	7	8	10	3
Other	50	40	30	23	-3
Total	**300**	**350**	**380**	**495**	**3.5**

The most significant market for hydrofluoric acid is the CFC industry, where anhydrous hydrogen fluoride is a raw material for the production of such fluorinated aliphatic hydrocarbons as CFC 12, 22, 11, 113, and 116, materials commonly associated with the refrigeration and air-conditioning industries. The developing social and government awareness of the threat that these materials represent to the earth's ozone layer as well as the significance of the ozone layer to ultraviolet filtering, has led to a reduction in consumption of these materials and a worldwide dedication to the development of chemical alternatives for these materials by the year 2000. These alternatives are likely to contain higher levels of fluorine, as chlorine atoms on the molecules are replaced by hydrogen as well as fluorine. The recent dip in demand for hydrofluoric acid in CFC production is therefore predicted to reverse. Acid demand for CFCs may almost double by 1995, according to forecasts by some producers.

Imports currently represent 40 per cent of total hydrofluoric acid consumption in the U.S. Both Mexico and Canada are significant exporters to the U.S. market.

Table 5.39
North American Hydrofluoric Acid Producers

Company	Location	Capacity (kt/year)
Allied Signal		
Allied Corp., Chemical	Geismar, Louisiana	80
Allied Canada	Amherstburg, Ontario	56
E.I. Du Pont de Nemours	La Porte, Texas	60*
Pennwalt Corp.	Calvert City, Kentucky	20
Total		**216**

* Largely for captive use.

Ontario is a significant supplier of hydrofluoric acid. Allied's plant regularly exports 35 kt, about 75 per cent of its output, to the U.S. Ontario is also Canada's largest consumer of the acid. Both Allied and Du Pont Canada produce CFCs in the province, accounting for about half of Canadian hydrofluoric demand or about 12 kt/year. Other significant markets are for the production of uranium hexafluoride and gasoline alkylate, about equal in market size. Not surprisingly, domestic production of acid dominates the supply, with only 400-1,500 tonnes imported annually. In 1987, imports jumped to 5,400 tonnes when Allied had production problems, but they were resolved in that year.

The growth potential in fluorine chemicals is in flux. Should CFCs as a group not come under a total ban in North America, there could be attractive growth potential. Even with a ban there would be a solid market base for fluorspar supply, based on replacing imported material.

The outlook for hydrofluoric acid growth in consumption—and growth in demand for fluorspar—is closely tied to the success of efforts to replace the use of fluorocarbons in refrigeration and air-conditioning applications. The success in 1978 in the replacement of fluorocarbons in aerosol propellants has encouraged the effort to replace them in refrigeration and air-conditioning uses. Higher fluorine types of CFCs may be adopted as the replacements, spurring growth of hydrofluoric acid demand. The aerosol application accounted for 290 kt of fluorocarbon usage in 1974—before the 1978 U.S. EPA and FDA bans on non-essential aerosol use of halogenated fluorocarbons—while today less than 10 kt of fluorocarbon are used in this application. This market for CFCs is not expected to revive dramatically. The third usage, that of a blowing agent in plastic foams, is also under attack, but here too a new generation of CFCs could boost hydrofluoric acid consumption.

Fluorspar Market

The regional market for fluorspar lies in both the hydrofluoric acid area as well as steelmaking and other applications. However, the acid-grade material generally coming into Ontario generally from Mexico dominates the regional market and would seem to provide an opportunity for an industrial mineral producer.

Fluorspar imports into Canada have been ranging from 135 to 194 kt. The low point in 1987 was due in part to a closure of Allied in Amherstburg for a few months, and that disruption caused both imports of acid into Canada to occur as well as a slowing of rock imports.

Table 5.40
Fluorspar Imports into Canada

	1986	1987	1988
		($ millions)	
U.S.	2.4	2.2	2.6
Morocco	4.5	3.2	4.9
Mexico	11.3	7.6	15.3
China	0.5	1.7	1.9
Others	4.0	3.1	1.8
Total	**22.7**	**17.8**	**26.5**

Source: Statistics Canada

The above figures include both 97 per cent and over calcium fluoride and under-97 per cent material. About 70 per cent of the material being imported into Canada from Mexico and other sources is the higher-quality material required for hydrofluoric acid production and some other applications.

Table 5.41
Volume of Fluorspar Imports into Canada

	1986	1987	1988
		(kt)	
U.S.	10.6	8.9	12.3
Morocco	27.6	22.5	34.0
Mexico	87.6	66.6	120.6
China	4.8	14.4	14.0
Others	33.5	22.2	13.2
Total	**164.1**	**134.6**	**194.1**

Source: Statistics Canada

From a supply of rock basis, Ontario obtains most of its needs from Mexico, with a little coming in from the U.S. and a few other countries. Material from Mexico accounts for the bulk of the acid demand in the province.

Table 5.42
Value of Fluorspar Imports into Canada, 1988

	CaF_2>97% ($/tonne)
U.S.	247
Morocco	143
Mexico	126
China	136
Average	**134**

The product value varies somewhat, with the U.S. material obtaining a premium and Mexican material at the low end of the value-scale.

There are two fluorspar producers of note in the U.S. and their plants fall within the general regional market. These facilities would supply the small amount of material that comes into Canada from the U.S.

Table 5.43
U.S. Fluorspar producers

Company	Location	Capacity (kt)
Pennwalt Corp.		
Ozark-Mahoning subsidiary	Illinois	65
Diversified Mineral Corp.	Kentucky	35

For the higher-quality fluorspar product in North America, acid plants form the market. The Gulf Coast hydrofluoric acid plants produce for the bulk of the U.S. fluorine products market, but the Canadian hydrofluoric acid plant is of comparable size in the continental context.

Ontario is a sizable market for acid-grade fluorspar. Allied-Signal's plant at Amherstburg obtains fluorspar mainly from Mexico, there being no acceptable domestic source nearby. There is a suitable fluorspar deposit at St. Lawrence, Newfoundland, but it is bottlenecked by poor shipping facilities. The harbor can only accept ships with a maximum 5,000-ton draft. Allied took a boatload in 1988, but prefers shipments of 18,000-ton lots.

Process technology

Manufacturing process

The production of hydrofluoric acid from fluorspar ore can be accomplished by beneficiation of the ore by sorting, gravity separation, and finally by froth flotation. The acid production step involves reaction with hot sulphuric acid which generates hydrogen fluoride gas, which in turn is dried in sulphuric acid and condensed by refrigeration. The resultant anhydrous hydrofluoric acid form is then commonly shipped "as is", though a 70 per cent aqueous solution of hydrofluoric acid can also be produced.

Discussion of potential

Raw material requirements

There are several grades of fluorspar used in various markets. The lowest grade is metallurgical, used where the specifications tend to call for calcium fluoride over 60 per cent. Ceramic grade material falls into two classes: 85-90 per cent calcium fluoride and 95-96 per cent calcium fluoride.

Acid-grade material tends to have the highest specifications of the volume uses and requires over 97 per cent calcium fluoride levels, plus control of contaminants.

Table 5.44
Typical Hydrofluoric Acid Grade Fluorspar

Calcium fluoride	97%	min.
Silica	1%	max.
Sulphur	0.03%	max.
Calcium carbonate	1.25%	max.
Heavy metal oxide	<0.4%	
Water	<0.1%	

While the natural grade of ore in Ontario is unlikely to reach acid grade with ease, developments in beneficiation technology might be utilized to upgrade local ores to serve the regional market. Several firms have worked on froth flotation technology that could have application in upgrading local fluorspar to acid grade.

American Cyanamid of Wayne, New Jersey has patented a collector system that involves esters of polycarboxylic acid. The system is highly selective and offers the advantage of mill water capable of being recycled.

Cyanamid has developed a second process that replaces a conventional tall oil diluted in fuel oil with a secondary alcohol diluted in fuel oil. An alternative is to use an ethoxylated 2 deg. alcohol instead. This process is also claimed to be highly selective and capable of producing a cleaner product than conventional processes. Apparently the use of an alkali further improves the yield and grade of fluorspar ore being upgraded.

Dow Chemical of Midland, Michigan has also developed flotation reagents suitable for processing fluorspar. One of the firm's processes involves a solvent containing polyalkylene oxide compositions to improve fluorspar yields. A second Dow process involves a floating collector system using mercaptans of polyalkylene oxide.

While these flotation processes are not being used at present on local ores and much testing would be required to find a suitable process, the cost of processing for flotation processing probably runs at the $10/tonne level, provided a reasonable economic process can be proven. On a competitive basis with imported ores, this would be offset by the lower cost of transportation to the regional market.

Should there be a deposit that might be upgraded in

Ontario, the volume of rock that could be sold on the local market could encompass the 100-120 kt of material imported into Canada. Potentially, supply to the acid plant in Kentucky could also be considered. Additional volume might be obtained in the metals sector, where fluorspar is also used. The total potential market could therefore run in the 150 kt-a-year range in the future.

Growth outlook and timing of opportunity

The merchant U.S. hydrofluoric acid business is controlled by the sole remaining significant merchant U.S. producer, Allied-Signal Corp., and exporters to the U.S. in Mexico and Canada. With the avowed purpose of eliminating the use of traditional chlorofluorocarbons, highly fluorinated types are expected to be adopted, fuelling growth for hydrofluoric acid. However, if such new CFCs are not accepted as a solution, CFC production and its demand for hydrofluoric acid would decline through 1995 and then drop dramatically by 2000. The belief is that this should not happen, since there appear to be no viable alternatives to CFCs on the horizon.

The production of hydrofluoric acid will likely fall short of demand in the coming years, providing CFCs are not banned altogether and replacement CFCs are allowed for Freon-11. Projections are that CFC demand could go from 95 kt to 140 kt per year in the U.S. market, which relies on total imports of 100 kt of product today. Allied-Signal at Amherstburg exports 35 kt to the U.S. now, but an increase in demand by 1.2-1.5 times may occur, which would present a larger market in Canada and the United States for the output of that plant.

Should the new generation of high-fluorine CFCs gain acceptance, the Allied plant at Amherstburg would become an even more important supplier to the fluorocarbon plants in the northeast. Correspondingly, the demand for fluorspar should increase from present levels.

Within the next two to three years, the work by Du Pont, Allied, Pennwalt and European CFC producers are likely to be coming to market and gaining both market and regulatory acceptance. At that point, the longer term demand outlook for hydrofluoric acid will be more ascertainable.

In terms of supplying suitable rock to the Allied-Signal plant in Ontario, there is not likely to be a basic problem, despite Allied's investment in mines in Mexico. The trial of Newfoundland rock provides some indication of potential interest in alternate suppliers of fluorspar.

Other technology and business factors

The potential opportunity for a fluorspar deposit owner in Ontario would seem to exist on an initial examination. Obviously technical factors on a deposit and the ability to work with Allied Chemical Canada to meet their needs for rock would be critical for the success of any project.

As indicated previously, Allied has been willing to try ores from various sources, despite the fact that the firm has a position in mines in Mexico that produce fluorspar.

The base demand for hydrofluoric acid could be strong and the market potential could increase in the next three to four years. Ontario has two strong regional producers of CFCs in Allied-Signal and Du Pont Canada. Their use of fluorine may increase, should the CFC market move to higher-weight products.

Sodium Cyanide

Basis for opportunity

Sodium cyanide (NaCN), produced by reaction between hydrogen cyanide (HCN) and sodium hydroxide (NaOH), is consumed mostly as a leaching reagent in the production of gold. A significant increase in world gold mining activity in recent years, largely in Canada, the United States and Australia has stretched the supply capabilities of sodium cyanide producers around the world.

The regional market in Ontario and Quebec has increased significantly from 1987 to 1988 and, even with the expansion of Cyanamid Canada's plant at Niagara Falls, Ontario making calcium cyanide, there may be an opportunity for another plant in Ontario making sodium cyanide.

The factors for an opportunity in sodium cyanide are as follows:

- Ready access to raw materials
- No pure sodium cyanide producers in regional market—transportation advantage
- Users very receptive to local supplier
- Cost-competitive with import sources
- Availability of production technology

Markets and producers

Continental market for sodium cyanide

Sodium cyanide is used primarily as a chemical reagent in the extraction of gold and silver. The size of the U.S. market for sodium cyanide in 1987 was about 52 kt. At an average price of $(Cdn.) 2,000/tonne, total market value was around $(Cdn.)105 million. With the addition of the Canadian market which runs to $(Cdn.)27 million per year, the total North American demand for sodium cyanide comes to $(Cdn.)132 million. Additionally, calcium cyanide, which competes with sodium cyanide in applications where its lower strength, calcium oxide and sodium chloride contents are not a problem, represents approximately $(U.S.)15-20 million in Canadian domestic and export sales.

The U.S. market for sodium cyanide is expected to grow at an average annual rate of about 10 per cent. Some growth estimates are as high as 15 per cent, and have been advanced in anticipation of rapid increases in gold mining activity. Technological change in gold and silver extraction methods is not expected to affect this market within the next 10 years.

Table 5.45
North American Market Outlook for Sodium Cyanide

	1987	1988 (kt)	1995	Growth Rate '88-'95 %
U.S.	45	52	100	10
Canada	12	18	36	10
Total	**57**	**70**	**136**	**10**

There is no production of sodium cyanide in Canada, so all Canadian users must rely on imported material. Some consumers can use calcium cyanide as an alternative. In 1988 one-third of the material was brought in from the United States, being shipped from Tennessee. Other major exporters to Canada included Germany and the United Kingdom.

Table 5.46
North American Supply/Demand

	U.S.	Canada (kt)	Net North American Total
Capacity	100	-	100
Production	80	-	80
Offshore imports	13	12	25
(U.S. to Canada)	(-)	(6)	(6)
Net total supply	93	18	105 Net
Domestic demand	52	18	70
North American Exports	41	-	35 Net

The primary use for sodium cyanide is extracting gold and silver from ores. These metals are readily soluble in a weak solution of cyanide. Other applications for the chemical include: production of hydrocyanic acid for further chemical reaction, metal cleaning, production of chelating agents, nylon intermediates and various chemical reactions including production of dyes and pigments.

Table 5.47
North American Sodium Cyanide Applications

	1988 (kt)
Gold production	53
Other mining applications	6
Metal plating	3
Chelating agents (EDTA)	1
All other uses	7
Total domestic demand	**70**

Source: Law, Sigurdson & Associates and SRI International estimates

In gold production, sodium cyanide can be applied in dilute solution, i.e. 0.1% wt., over gold ore to extract the metal. The ore is typically placed over large plastic holding ponds, and most of the cyanide is recycled. As an option, vat leaching can be carried out with cyanide. Further processing steps can also require sodium cyanide to extract gold.

In the mining applications, calcium cyanide can compete with sodium cyanide. Whereas calcium cyanide can be used in the heap leaching step, sodium cyanide is required for the carbon desorption step in gold production.

Regional market for sodium cyanide

In Canada, cyanide demand is largely dictated by its use in the mining industry. In addition to gold and silver production, copper/zinc mills also use the chemical.

Table 5.48
Canadian Sodium Cyanide Consumption

	1987	1988 (kt)	1988 (%)
Ontario	4	6	34
Quebec	3	4	22
British Columbia	2	4	22
Northwest Territories			
Yukon	2	2	11
All other areas	1	2	11
Total	**12**	**18**	**100**

Chemical synthesis requiring the cyanide ion in Canada must rely on sodium cyanide for the source. Production of chelating agents (EDTA) in Quebec by Clough Chemical, for example, uses imported sodium cyanide. Much of chemical synthesis requirements for cyanide in the United States are met by hydrogen cyanide, usually supplied by pipeline.

Sodium cyanide demand increased sharply between 1987 and 1988. Among the factors for this upturn in demand are:

- increased gold production due to higher metal prices;
- extraction from lower quality ores requiring higher dosages of cyanide.

The upshot was an almost 40 per cent increase in sodium cyanide demand between 1987 and 1988. That sharp trend is not expected to continue into 1989, although, according to one industry source, demand should still increase by 15 per cent in 1989 across Canada, and probably across North America.

Table 5.49
Gold Production in Canada

	1987	1988 (tonnes)	1988 (%)
Ontario	46.6	56.8	45
Quebec	29.5	32.5	26
British Columbia	11.2	13.0	10
Northwest Territories	11.7	11.4	9
Yukon	4.7	4.3	3
Manitoba	3.7	4.3	3
Saskatchewan	1.0	2.1	2
All other areas	1.1	2.3	2
Total	**109.5**	**126.7**	**100**

Gold production was not the only impetus to higher demand for sodium cyanide in 1988. Chemical usage for production of chelating agents (EDTA) also increased in the order of 20-30 per cent in 1988. Demand for chelating agents in the pulp and paper industry as hydrogen peroxide bleach stabilizer is increasing in Canada.

United States

The demand for cyanide in the United States generally follows the gold mining industry, and much of that industry is situated in the western U.S. Nevada produces nearly 60 per cent of the gold, while California is the second-largest gold-producing state.

Table 5.50
United States Regional Gold Production

	1988 ('000 Troy Ounces)	1988 (%)
Nevada	3,714	57
California	710	11
Northern states *	1,103	17
All other areas	947	15
Total 1988 production	6,474	100
Total 1987 production	4,966	
1988 increase in production		30

* See Table 5.51 below

There is not a significant sodium cyanide gold requirement in the northeastern U.S. Only Michigan and South Carolina are eastern gold-producing states. Therefore, the regional U.S. market for an Ontario sodium cyanide producer would be more in low-volume accounts in chemical synthesis, metal plating etc.

Table 5.51
Major Gold-Producing States in Northern U.S.

	Major Mines (number)	1988 Production (Troy Oz.)
Montana	4	304,327
Idaho	4	71,658
Washington	2	n/a
Michigan	2	n/a
South Dakota	1	n/a
Oregon		neg
Total	**13**	**1,103,833**

n/a - not available
neg - negligible

In the regional market of Ontario/Quebec and northeastern U.S. there is competition between sodium and calcium cyanide at the mining companies. The technical aspects of using sodium versus calcium product is determined by some ores with high carbonate contents, but in most instances either cyanide can be used in the gold refinery and the two products compete on a cyanide basis.

Calcium and sodium cyanide markets

The sodium cyanide market can be considered a subset of the total calcium and sodium cyanide market, in that the two materials compete for the same applications.

Table 5.52
Estimated Canadian Cyanide Consumption by Type

	Calcium*	Sodium (kt)	Total
Ontario	5	6	11
Quebec	2	4	6
British Columbia	-	4	4
Northwest Territories			
Yukon	-	2	2
All other areas	-	2	2
Total	**7**	**18**	**25**

* 100% sodium cyanide equivalent basis

Position of calcium cyanide in the region

Calcium cyanide ($Ca(CN)_2$) is used as a chemical reagent in the extraction process of gold and silver. It also finds some use in electroplating. Calcium cyanide competes with sodium cyanide (NaCN) in mining extraction.

There is only one producer of cyanide products in Canada. Cyanamid Canada produced about 18 kt (9 kt on a NaCN basis) of calcium cyanide. Based on current pricing of $1.10/kg (100 per cent NaCN basis), total market value is estimated at over $(Cdn.)12 million. Most of the calcium cyanide production is sold to the Canadian market.

The predominant use of calcium cyanide is as a leaching agent. We estimate that 80 per cent of the product is used in this market. In this application it competes directly with sodium cyanide and therefore is priced appropriately. Lime (CaO), which is needed to modify pH (increase) with sodium cyanide extraction, is not needed with calcium cyanide extraction. The mining companies therefore get their pH adjustment free.

Current gold mining/refining technology also involves the use of sodium cyanide as a stripping agent to remove and at once concentrate the precious metals from activated charcoal absorbents. Calcium cyanide does not compete in this application, and only the more reactive and more pure sodium cyanide is employed. Calcium cyanide is also used as a depressant in copper mining. It serves to prevent the flotation of pyrites.

Unlike sodium, calcium cyanide is shipped in bulk as a powder, containing a mix of impurities, while the sodium cyanide is typically shipped in drums. Typically, the product has 46-48 per cent cyanide expressed as 100 per cent sodium cyanide, along with significant quantities of calcium oxide and chlorine.

Some consumers could technically use either calcium or sodium cyanide in their process if they require sodium in one part of the operations, however, they could be reluctant to handle both of these hazardous chemicals. This may reduce the

marketability of the calcium cyanide at some accounts.

Production of calcium cyanide

The only producer of calcium cyanide in North America is Cyanamid Canada at Niagara Falls, Ontario. Current capacity for the Niagara Falls facility is roughly 20 kt per year, or 10 kt on a sodium cyanide basis. Cyanamid recently doubled its calcium cyanide capacity at a cost of $2 million.

Calcium cyanide is manufactured at Cyanamid Canada's Niagara Falls in conjunction with calcium carbide production operations. To produce calcium cyanide, crude calcium cyanamide is heated in an oven at a temperature above 1000°C with sodium chloride.

Cyanamid's calcium cyanide business is an integrated, relatively small portion of the company's calcium carbide operations. Nevertheless, the cyanide business is able to take advantage of economies of scale due to the integration, as well as the operation's low raw material costs. Cyanamid prices its calcium cyanide to be competitive with sodium material.

Cyanamid once had six large electric arc furnaces in Niagara Falls for the production of calcium carbide. Now only two furnaces use the lime and the coke to make calcium carbide. Total capacity for calcium carbide in Niagara Falls is currently about 130 kt per year (60 per cent calcium carbide, with lime).

Prices for sodium cyanide

Prices for sodium cyanide have increased substantially from 1986 levels due to several reasons. On the demand side, new gold mines have opened up, requiring additional product. New mines are going into production, not only in North America, but also in Oceania, New Guinea and other countries. The total worldwide demand for cyanide increased 15 per cent between 1987 and 1988.

Table 5.53
Delivered Prices for Sodium Cyanide (distributor prices)

	1986	1987	*H1-1988	H2-1988	1989
			($Cdn./tonne)		
Contract	1,500	1,750	2,500	3,000	3,000
Spot	1,500	1,750	4,000	5,000	3,500

*H1=first half of 1988

Producers around the world in the United States, United Kingdom, Italy, Brazil and Germany operated plants to maximize output as a result of the increasing demand, but eventually several plants had operating problems, so the supply became tight. Additionally, some operators had to take shutdowns to put in expansion capacity.

The result was a sharp increase in prices towards the beginning of 1988, continuing during most of 1988. Spot prices shot up to as high as $5.00 per kg, while contract prices reached $3.00 in Canada. There was some relief in 1989, with spot prices declining somewhat to the $3.50 level.

Trade in sodium cyanide

Sodium cyanide is a commodity chemical, shipped around the world from the major production centers. The United States, United Kingdom, Italy and West Germany are major exporting countries. Australia, Canada, Mexico and Chile are a few of the major importing nations.

Table 5.54
Sodium Cyanide Importers to Canada

	1986	1987	1988
		($ millions)	
U.S.	4.5	5.8	9.1
United Kingdom	3.7	5.4	7.0
West Germany	1.6	1.6	5.5
Italy	0.2	0.3	1.5
East Germany	0	0	1.0
Others	1.1	1.1	3.4
Total	**11.1**	**14.2**	**27.6**

Source: Statistics Canada

Most of the material coming into Canada is produced in Europe and enters Canada through Quebec. The imports into Quebec are greater than that province is believed to consume. Distributors and the branch marketing offices of the producers handle the sales in Canada.

Table 5.55
Distribution of Canadian Imports of Sodium Cyanide

	1986	1987	1988
		($ millions)	
Quebec	4.0	5.7	12.2
Ontario	2.9	3.9	2.5
Manitoba	1.1	0.8	1.5
Other provinces	3.1	3.8	11.4
Total	**11.1**	**14.2**	**27.6**

Source: Statistics Canada

Du Pont seems to have contractual obligations to supply Australian mining interests, so the company has backed down on significant portions of the North American market. Inevitably, some large users of the chemical may well resort to at least two sources of material. ICI from the United Kingdom and Degussa have taken advantage of the increased North American demand to position product in Canada and the United States.

Table 5.56
Estimated* U.S. Imports —1988

	kt
United Kingdom	4.5
W. Germany	4.1
Italy	1.3
Korea	1.1
Japan	0.4
All other	1.2
Total imports	**12.6**

* extrapolated from 11-month data.

Australia is using significant volumes of sodium cyanide for mining applications, and Du Pont seems committed to supplying a major portion of the business from the U.S. Gulf Coast production facility. Apart from Mexico, Canada and Chile, there are a host of other countries purchasing lower volumes from the United States.

Demand in Australia increased significantly from 1987 to 1988 to the point that ICI plans to bring a 22 kt plant on-stream in 1989. That could have the effect of reducing that country's imports by 1990.

Table 5.57
U.S. Exports of Sodium Cyanide

	1987	1988	1987	1988
		(kt)	($U.S. million)	
Australia	14.3	19.5	13.3	20.1
Mexico	5.5	4.9	6.6	6.1
Chile	4.4	5.2	4.4	6.1
Canada	4.1	5.5	3.7	5.0
All other	4.8	6.2	4.9	7.0
Total	**33.1**	**41.3**	**32.9**	**44.3**

Supply of sodium cyanide in North America

Sodium cyanide has been traditionally a chemical supplied to some extent by domestic manufacture and the balance from imports from Europe.

There is presently only one producer of pure sodium cyanide in North America: Du Pont at Memphis, Tennessee. However, additional capacity is under construction or consideration that could add 130 kt to the present 100 kt of capacity. Given the dynamics of the cyanide market, some market analysts are expecting that not all the plants being planned will be actually built.

Table 5.58
North American Producers of Sodium Cyanide

Company	Location	Status	Capacity (kta)	Notes
Du Pont	Memphis, Tennessee	OPR	100	
		EXP	20	Recent expansion
	Texas City, Texas	UCT	30	On stream shortly
		EXP	20	On stream by year end
	Mexico	UCT	10	On stream shortly
FMC	Green River, Wyoming	PLN	22	1990 start-up
Degussa	Mobile, Alabama	PLN	30	1992/93

OPR - Operational
EXP - Expansion
UCT - Under construction
PLN - Planning

The current major suppliers of sodium cyanide have traditionally had a strong position in the supply of mining chemicals. Du Pont has long been an established supplier of explosives in North America, as well as other mining chemicals. ICI (C-I-L in Canada) and Degussa have been suppliers to mining companies in North America and around the world.

The major world sodium cyanide producers and their Canadian affiliates as follows:

Du Pont, Memphis, Tennessee
Du Pont Canada, Calgary, Alberta
Degussa, West Germany
Degussa Canada, Burlington, Ontario
ICI Chemicals, United Kingdom
Stanchem, Toronto, Ontario

In addition to the expansions listed above, Cyanamid Canada has recently expanded its calcium cyanide plant at Niagara Falls, Ontario to bring its capacity to 20 kt of calcium cyanide (10 kt of 100 per cent cyanide). The present capacity

is in excess of the Ontario mining industry requirements, and some product is being exported to Latin America and Oceania. Cyanamid plans to capitalize on the future growth in gold mining, which they expect to occur mainly in the west.

Process technology

Manufacturing process

Production of sodium cyanide is often a two-step process. Cyanide is produced and then reacted with sodium hydroxide to manufacture the final product.

Hydrogen cyanide (HCN), the raw material for sodium cyanide production is itself produced from the reaction of ammonia and methane (natural gas) in the presence of a platinum-type catalyst. In some cases, the hydrogen cyanide used can be the by-product of nearby acrylonitrile production.

The only present U.S. producer of sodium cyanide, Du Pont at Memphis, Tennessee, produces liquid hydrogen cyanide primarily for the production of other end products (Plexiglas). They produce sodium cyanide briquettes starting with liquid hydrogen cyanide. The new Du Pont plant under construction at Texas City, Texas will be based on by-product hydrogen cyanide from a nearby acrylonitrile plant owned by Sterling Chemical.

Basic technology on cyanide and sodium cyanide manufacture is available from several sources, with cyanide production being the critical step in manufacture. Hydrogen cyanide production technology should be available through licensing. Du Pont has licensed its technology to Ciba Geigy and FMC reportedly is negotiating with other companies to license its technology. Rohm & Haas, Bayer, and Mitsubishi are also believed to have technology which can be licensed.

An interesting side-light on hydrogen cyanide technology lies in Canada at Shawinigan Chemicals. As Gulf Chemicals, the firm developed a production method for generating a high-purity stream of gas. The process involved a Fluohmic furnace that had a fluidized bed of coke heated to 1,350 -1,650°C. Current was passed between electrodes immersed in the bed and a feed gas mixture of ammonia and a carbon source, such as propane, was introduced into the furnace. Both high yields and apparently high concentrations were claimed for the process. Shawinigan Chemicals was the last sodium cyanide producer in Canada, with the plant closing more than a decade ago.

FMC'S Green River project

The FMC project in Wyoming is somewhat illustrative of the type of investment and plant profile that could fit in an Ontario setting. With no Canadian acrylonitrile plants, for by-product hydrogen cyanide sources in the province, production of the raw material would have to be undertaken.

FMC is planning to build a 22 kt sodium cyanide plant at Green River, Wyoming to be on-stream about mid-1990. Ground is now being broken for the caustic soda part of the operation which does not require any special environmental approvals. FMC will be making a total investment of $(U.S.)40-45 million. This includes separate facilities for the production of caustic soda and sodium cyanide, and a rail spur and transloading facility in Nevada. The plant expansion at Green River will provide about 30 new jobs.

In the mid 1980s FMC initiated solution mining of soda ash at Green River, Wyoming, after having spent $(U.S.)30 million in research and development for the process.

The Green River plant already produces a weak caustic solution, and this fact is one of the reasons for building the new facility at this location. This solution will have to be concentrated prior to entering the sodium cyanide reaction; the implication is, however, that the capital cost of the plant does not include at least a portion of the caustic production that would be required at a stand-alone site.

The plant will make hydrogen cyanide by the Andrussow Process from methane and ammonia. The basic reaction is:

$$2NH_3 + 2CH_4 \longrightarrow 3O_2 + 2HCN + 6H_2O$$

The hydrogen cyanide will be recovered as a gas, and reacted with caustic soda to produce a 30 per cent sodium cyanide solution. The basic reaction is:

$$HCN + NaOH \longrightarrow NaCN + H_2O$$

Ammonia use efficiency in the plant will be about 65 per cent. The efficiency of methane use will probably be less than 60 per cent. The plant will require about 15,000 tonnes of ammonia annually, probably sourced from Western Canada. FMC apparently will also use natural gas (methane) from a company- owned source.

Normally, hydrogen cyanide is recovered as a liquid and the recovery and use of the hydrogen cyanide as a gas at the Green River plant represents a novel, but not unique, variation. There is a similar plant operating in Australia. The production of sodium cyanide as a solution for direct use by customers is also novel as compared to the normal crystallization and briquetting before shipment. The viable marketing area for this plant is expected to be Nevada to Montana and as far east as Homestead in the Dakotas.

Discussion of potential

Raw material availability

Ontario is in a favorable raw material position with respect to the basic production of sodium cyanide. The province boasts world-scale ammonia plants, pipelines capable of supplying natural gas and a well-developed chloralkali industry in Ontario and Quebec that can supply caustic. Salt is readily available from the Sarnia-Goderich area.

Pricing of both ammonia and caustic in the province is done at continental prices and with a commodity such as ammonia there perhaps could be seasonal discounts. Ammonia for direct use in agriculture is highly seasonal, and off-season special pricing might be possible in the province.

The impact on industrial minerals of cyanide manufacture in the province would be only the derived demand on salt through a new caustic demand in Ontario. For the minerals industry in the province, however, a larger supply of cyanide

would provide a needed material for the increasing gold production in Ontario and Quebec.

Growth outlook and timing of opportunity

Predicting the growth in demand of sodium cyanide for gold producting applications, is difficult, because the volume used can swing significantly with the price of the precious metal on world markets. We have assumed a 10 per cent growth rate to 1995.

Our projection on cyanide use could be conservative, depending on the price of gold. Some industry sources have predicted 15 per cent growth. It is perceived that when gold runs over $(U.S.)400 an ounce, gold mining increases solidly, and the mining slowly tails off as the price drops below $350 an ounce. As a result, many industry watchers are expecting gold production to rise by levels of 10-15 per cent and cyanide consumption along with it, over the next five or more years.

Table 5.59
Forecast North American Supply/Demand

	1988	Case 1 1995 (kt)	Case 2 1995
Capacity			
Du Pont	100	170	170
FMC	-	22	22
Degussa	-	30	30
Possible Ontario facility	-	-	30
Total announced capacity	100	222	252
Production	80	175	202
Imports	25	-	-
Total supply	105	175	202
Domestic Demand			
- U.S.	52	100	100
- Canada	18	36	36
Total domestic demand	70	136	136
Total exports	**35**	**39**	**66**

There are new mines coming into production as the price of gold has increased over the past several years. Current production costs leave enough margin to keep plants operating and allow some new ones to come on-stream.

Although demand is assumed to be growing at relatively high rates, the capacity build-up in North America will be even faster so that, capacity should still exceed demand by 1995. This is based on announced capacity from the major producers.

For North America as a whole, domestic production will have to be exported to fill out plant capacities. A scenario that involves an Ontario operation would involve forcing Southern U.S. producers to export their output. Additionally, an Ontario-based plant would have to replace much of the offshore imports heading into Canada at the present rate.

Table 5.60
Regional Market Coverage for Ontario Plant (Sodium Cyanide Only)

	1988	1995 (kt)	1995 Share Needed (%)
Ontario	6	12	80
Quebec	4	9	80
British Columbia	4	8	70
Northwest Territories, Yukon	2	4	50
All other areas	2	3	50
Total	**18**	**36**	**75**

The opportunity in Ontario is based more on being a strong regional supplier. There would seem to be enough market coverage to fill out the major portion of a 30 kt plant. An Ontario producer would have to capture nearly 80 per cent of the eastern Canadian market, as well as a major portion of western Canadian market, moving material by railcar to as far away as British Columbia and the Territories. If Du Pont can place material in the western mills by transporting it from Tennnessee, then an Ontario-based plant should be able to compete on transportation. If the concentration of the product is on the order of 30-40 per cent, however, then the plant's market will be concentrated regionally.

An Ontario facility could be sized to supply a 22-27 kt market, with a strong emphasis on sales in Ontario and Quebec. In the eastern Canadian market, an Ontario producer should have an advantage over European imports. Not only would there be a transportation advantage, but the producer could sell directly, eliminating distributor mark-ups.

Base metal and gold mills contacted as part of our study were very favorable to the idea of an Ontario producer of sodium cyanide. They would be receptive to the establishment of long-term supply contracts to assure a secure source of material for their operations. At one time Placer Dome, for example, was even considering installation of a sodium cyanide production facility to ensure a secure source for its own needs.

Impact on Industrial Minerals of Ontario

The impact of the potential chemical opportunities on the industrial minerals sector of Ontario will be highly varied. The demands of any of these chemical opportunities, if successfully implemented, may not result in the opening of many or any mines. However, the opportunities can provide potential additional market or potential value-added for the existing mineral sector in the province.

Table 5.61
Maximum Tonnage Potential for Minerals

	Raw Material	Mineral Requirement Annual Volume (tonnes)
Hydrofluoric acid	Fluorspar	150,000+
Calcium carbonate, precipitated	Lime	50,000+
Barium chemicals	Barite	25,000
Colloidal silica	Sodium silicate	5,000
Sodium silicate	Silica	50,000
Cyanide	Caustic soda/salt	15,000

There are already opportunities to supply minerals such as fluorspar, limestone and silica to the chemical producers of the province, if local materials could offer acceptable specifications for import replacement.

The dollar volumes of the identified chemicals be judged to be sufficient to merit consideration for potential plant investment.

Table 5.62
Estimated Regional Market Volume

	Regional demand ($ million/year)
Cyanide	35
Fluorspar	25+
Calcium carbonate, precipitated	20+
Barium chemicals	16
Colloidal silica	5

The estimated timing of opportunities is closely linked to the growth outlook. It is estimated that products such as barium chemicals, cyanide and fluorspar have immediate potential. The opportunity for manufacturing of precipitated calcium carbonate is seen as two to five or more years from the present, and colloidal silica potential may not be realized for another five to ten years.